PRINCIPLES OF HYGIENE

THOMAS A. STOREY

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TEXTS ON HYGIENE

BY THOMAS A. STOREY

PRINCIPLES OF HYGIENE

Part I. *Principles of Constructive Hygiene*

The principles that ultimately determine and regulate the production, improvement, and maintenance of health

Part II. *Principles of Defensive Hygiene*

The principles that ultimately determine and regulate the defense of health and the prevention of disease

THE PRACTICE OF HYGIENE

(In preparation)

Part I. *Individual Hygiene*

Part II. *Group Hygiene*

The hygiene of the family, school, and occupational groups

Part III. *Intergroup Hygiene*

Societal or public hygiene

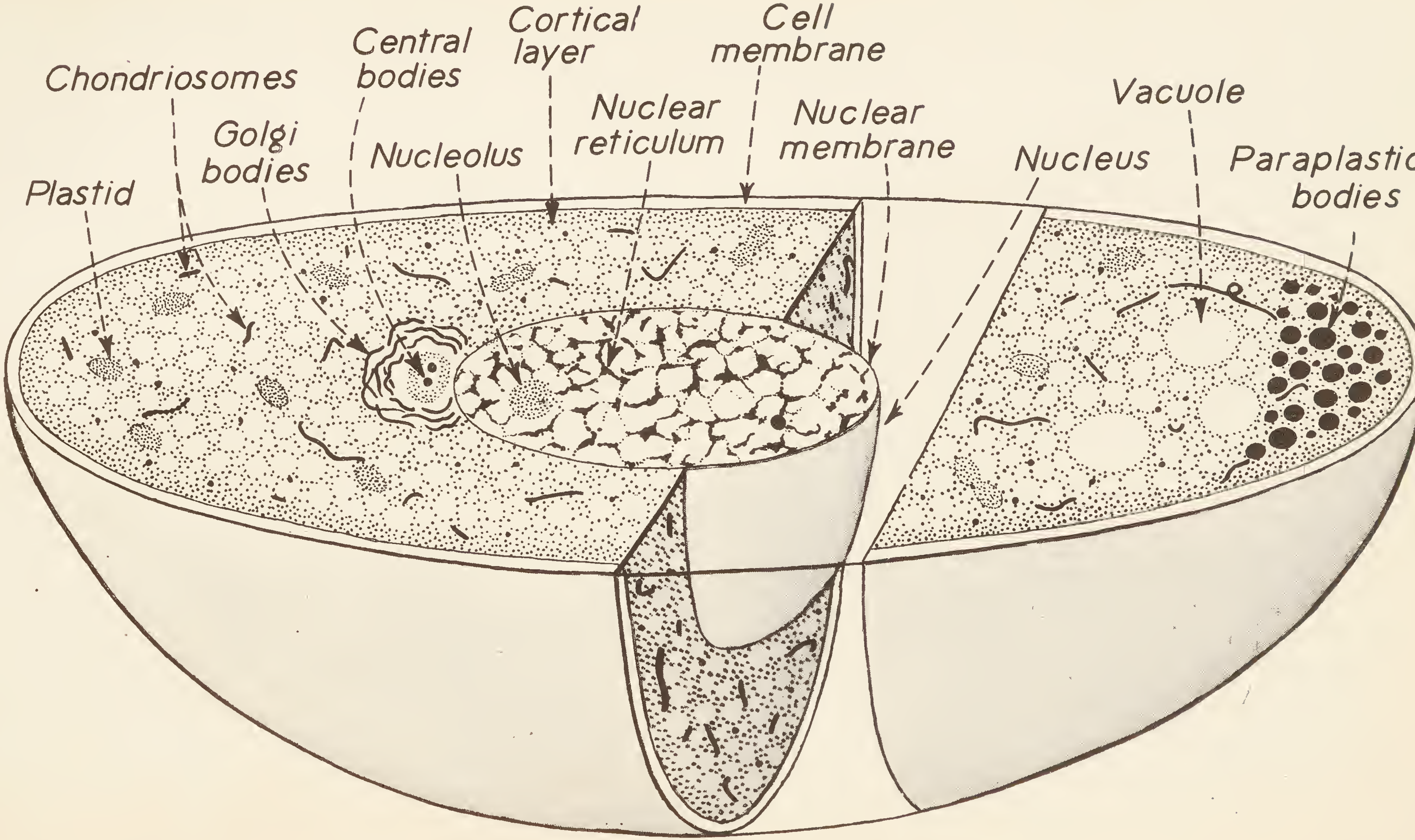

FIG. 1.—Diagram of a protoplasmic cell (modified from Wilson).
"Every living organism is or at some time has been a cell."

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BY

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DEDICATED TO

THE COLLEGE STUDENT—
A CITIZEN IN THE MAKING

PREFACE

This serial text on Informational Hygiene has been prepared in the hope that it will give the college student a basis for the formulation of rational, discriminating health judgments which will help exceptional youth condition itself for vigorous, enduring maturity; prepare him adequately for life-giving, health-producing, personality-building parenthood; equip him to meet successfully the logical life-saving and health-conserving obligations that helpless infancy, dependent childhood, co-operating maturity, and weakening age must place upon adult competency; train him constructively to be, for the far-reaching health betterment of society, the influential teacher that every college-trained person should be; and get him ready to satisfy the greater opportunities and the heavier consequent responsibilities for sane community health-leadership that are imposed upon the few selected for the precious opportunity of a college training for citizenship.

Thomas A. Storey

College of the City of New York
September 1924

PREFACE TO THE REVISION OF 1935

The revisions that I have made in this text are chiefly in chapters i to xii, inclusive, in Part I of this book. Most of these chapters have been almost wholly rewritten.

I am greatly indebted to Professor Harold Heath for his friendly assistance in the correction of certain errors and in the preparation of all the illustrations in chapters ii to xii, inclusive.

Thomas A. Storey

Stanford University
August 15, 1935

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CHAPTER I

THE MEANING OF PRINCIPLES AND PRACTICES, AND OF HEALTH, DISEASE, AND HYGIENE

The meaning of principles.—This text is concerned with the principles of hygiene. Another of our texts is concerned with the practice of hygiene. A principle is a cause or a fact or a truth that ultimately determines and regulates a consequent effect. The principles of hygiene are the causes or facts or truths that ultimately determine and regulate health. There are principles that determine and regulate the production, improvement, and maintenance of health. In this book these causes of health are described as principles of constructive hygiene because they may be interpreted as causes that determine and regulate the construction of health.

There are principles that ultimately determine and regulate the protection and defense of health and the prevention of disease. These principles are described in the second part of this book as the principles of defensive hygiene.

The meaning of practice.—It was noted above that another of our texts is concerned with the practice of hygiene. This other book deals with the behaviors of mankind that produce, improve, and maintain health and that protect and defend health or prevent disease. These behaviors are the forced and persuaded practices of hygiene. They may be unwitting or ignorant; or witting and wise or unwise; or informed and intelligent. The behaviors of the individual that produce, improve, maintain, protect, and defend his health constitute the practices of individual hygiene. The behaviors of the family group and of other groups that construct and defend the health of their members constitute the practices of group hygiene. The co-operative behaviors of groups (intergroup behaviors), the behaviors of the community, the public, the state (that is to say, the behaviors of society), that construct and defend health constitute the practices of societal hygiene. Such practices may be properly classified too as practices of "intergroup hygiene." These societal behaviors are composites of the practices—the habits, folkways, mores, beliefs, customs, institutions, and laws—of mankind that produce, improve, maintain, protect, and defend health in obedience to the principles of hygiene.

Signs of health.—Almost every one of us thinks he knows what health is. But when one tries thoughtfully to describe or define health, he finds the problem complicated and the analysis difficult. We recognize human health in the presence of such signs and symptoms as growth, development, and functional activity. Co-ordination, integration, feeling, remembering, thinking, and willing are signs of health. Adaptation to physical, biological, and social environments, a sense of well-being, ease, comfort, satisfaction, and happiness are signs and symptoms of health. No one of these evidences taken alone is proof of normal or complete health. The deficiency or absence of any one of them may be evidence of deficient health.

Growth a sign of health.—Growth is the most obvious indication of health in the beginning and during the earlier years of the life of the individual. The outstanding evidence of health of a fertilized ovum, formed by the union of a living sperm and a living egg with which every human life begins, is furnished by the fact that under the favorable environment furnished by the expectant mother the fertilized ovum grows into an embryo. It grows by a multiplication of its cells. Each healthy cell of a healthy embryo comes from the division of a preceding cell and it in turn grows by dividing into two cells. The daughter-cells produced by the divisions grow in the same way by dividing, until a foetus is formed by the multitude of cells produced and at last a child is born. The baby is a healthy baby if the fertilized ovum from which it grew was healthy, and if all of the millions of tissue cells into which that fertilized ovum divided, in order that it might multiply and thus grow into an embryo, a foetus, and finally an infant, were healthy. Growth by the division, and thereby the multiplication of tissue cells and by their orderly arrangement into tissues and organs, is the main evidence of health during the prenatal period and during the period of infancy.

Growth may be produced by an increase in the size of the tissue cells as well as by an increase in the number of tissue cells. After the prenatal period, the number of the cells of the body does not increase at the same rate as it did during that period. Growth then becomes principally an increase in size without a corresponding increase in number of cells. As infancy passes into childhood and then into youth, the outstanding evidence of health is demonstrated by growth in which an increase in the size of cells and

organs comes to be the main factor. Growth in size of cells is characteristic of youth and early maturity. Growth by increase in the number of tissue cells practically ceases with the completion of puberty except for repair of injuries and restoration of cells that have been destroyed. Even such growth is limited to certain kinds of cells.

The growth of an individual is evident in his increase in height and weight. We can measure growth roughly by measuring stature and weight. Thus we may secure measurements as evidence of health. Unfortunately growth in height or weight, or height and weight, is not conclusive evidence of health.

Development a sign of health.—"Development" is a term we apply to another sign of health. However, growth and development are largely synonymous in biology. The growth of an embryo is accompanied by the specialization of cells and their formation into tissues and organs. This specialization of tissue cells and the orderly formation of organs constitute development. The specialized tissue cells form the several tissues, such as muscle tissue, nerve tissue, gland tissue, and connective tissue. The tissues form the organs of the body, such as the skin, the heart, the lungs, the brain, the teeth, the stomach, and the bones. The organs form the embryo and the embryo at birth is a child. We may state that these tissues and organs "grow" from the original fertilized ovum or that they "develop" out of the cells produced by that original fertilized ovum.

Thus health is a product of normal growth in the number and size of tissue cells. It is also a product of the normal specialization of those cells and their orderly arrangement into organs, in a word, of development.

Normal function a sign of health.—Every cell, every tissue, and every organ has its normal functions. For example, contraction is a normal function of muscle cells. A muscle that does not contract is not a healthy muscle. The growth of muscle cells and the development of muscles supply the body with organs made out of muscle cells. The functional use (contraction) of these organs with the aid of the bones and of other integrating organs produces bodily movements. These movements are evidence of the health of the muscles and other organs that make these movements. The kicking and thrusting movements of the unborn babe and the sound of its beating heart are evidences of muscular functioning

that inform us of life and health. Again, vision is a function of the organs of the eye and of certain organs of the brain. The ability to see is an evidence of health. Hearing, smelling, tasting, and feelings of touch, temperature, and pain are examples of other functions, the presence of which is indicative of health of the organs that produce them. Consciousness, thinking, remembering, emotion, willing, the sense of satisfaction and well-being, comfort, harmony of mind, sociableness, and happiness are functions of mind. When normal they are signs of health.

Co-ordination of functions a sign of health.—The term "co-ordination" as used here is commonly employed with reference to the service of voluntary muscles. Co-ordination is the "team-work" among our muscles that enables us to perform orderly and useful movements. Without muscular co-ordination, the individual would be helpless. One cannot talk, write, stand, walk, eat, digest his food, dress, satisfy his intellectual interests, or otherwise meet the thousand and one demands and allurements of daily life without the co-ordinated activities of many muscles that must work together if these complicated movements are to be performed efficiently or even performed at all.

Integration of functions a sign of health.—For example, the voluntary movement of one's fingers or arm is an evidence of muscular co-ordination. It is also an evidence of an integration of a number of other functions that combine to make muscle contraction and movement possible. Among these integrated functions are those of the blood and lymph circulations that supply the muscles, bones, and joints of the fingers and arm with food, water, and oxygen and with the chemicals they need for their special functions. The service of the voluntary muscles is dependent also upon functional integrations with the nerves that associate the muscles with the central nervous system.

The performances of the organs of digestion, circulation, respiration, excretion, sensation, volition, reproduction, in fact the performances of any normal organ, are integrations of numerous contributory organic functions, each one of which is essential to the normal performance of the organ. All of the behaviors of the human being that constitute the phenomena of living are integrations of essential functions, every one of which must be active and normal if the individual is to be physically, mentally, or socially healthy.

Government of functions a sign of health.—Functions are governed by physical and chemical reactions, by hormones, by tropisms, reflexes, instinct, and by intelligent mind. It has been said that this government is a government by the mind and that for purposes of description there is a physical-chemical mind, a hormone mind, a tropic mind, a reflex mind, an instinct mind, and an intelligent mind. The mind of the normal human being is a combination or integration of these six sorts of government. Functions that are well governed are signs of healthy government. One's behavior as an individual is an exhibition of the quality of his government over his organic functions. The quality of his behavior is indicative of his physical, mental, and social health. It may indicate chiefly qualities of physical health, such as growth, development, maintenance, co-ordination, power, and vigor. It may indicate qualities of mental health, such as feeling, thinking, willing, comfort, satisfaction, and emotional adjustment; or it may display qualities of social health, such as sociability and friendliness.

Adaptation a sign of health.—If a tissue cell or a complex bodily organ performs its functions normally and serves its purposes usefully, it is safe to assume that it is adapted to its surroundings. Its adaptation to its environment enables it to continue its normal life.

The fertilized ovum that continues to live, and thus becomes an embryo, maintains its life because it is in a favorable environment to which it can and does adapt itself. The same necessity for adaptation exists in the life of the infant, the child, the youth, and the adult.

Roughly, the environment of a human being is first mainly a physical-chemical environment, then a physical-chemical and biological environment, and finally a physical-chemical, biological, and social environment.

The unborn child that for some anatomical, physiological, or unknown reason is not adapted to the normal physical (and biological) environment of the maternal womb is born deformed, deficient, damaged, or dead. If the physical-chemical prenatal environment is abnormal, the same results of poor adaptation may occur.

Assuming that food is the chief factor in biological environment, it follows that a difficulty or failure of the individual to

adapt himself to his biological (i.e., nutritional) environment means health difficulty, deficiency, or deprivation. This lack of adaptability may occur during any period, prenatal or postnatal.

Social adaptability becomes essential to individual health very soon after birth. Lack of adaptability to social environment becomes apparent as the child grows older, although some forms of maladjustment or of failure do not become evident until late youth or early maturity or even later.

Definition of health.—It is difficult to define health. This difficulty increases as our knowledge of the meaning of health increases. Today we recognize health of the individual as a bodily state, a mental state, and a social state. Yesterday mankind thought of health as simply a bodily or physical condition; mental health and social health had not been apprehended. Day before yesterday, perhaps a hundred thousand years ago, the conception of health had probably not been discovered anywhere in whatever may have been human society at that time.

Yet the health of the individual has always necessarily been a combination of bodily, mental, and social health. This is true of primitive man and of cultured man. It is true of the illiterate, of the ignorant, and of the wise. The health of the infant, the child, or the adult is a composite physical, mental, and social state and must be so regardless of the maturity, experience, culture, ignorance, or misinformation of the individual, the group, or the entire society of which the individual is a member. We may define health accordingly under three heads.

Somatic[1] *health.*—The health of the body, physical health, structural health, or organic health, may be designated "somatic health." The normal growth, development, and maintenance of the organs of the body and the normal co-ordination and integration of those organs and their functions constitute somatic health. The signs and symptoms of somatic health are growth, development, strength, endurance, co-ordination, skill, vigor, functional activity, bodily comfort, and longevity.

Mental health.—A mind that is healthy is a mind that has developed normally, exhibiting normal reactions, interests, urges, drives, volitions, emotions, and controls. Mental health is displayed in dynamic energy, rational happiness, serene temperament,

[1] From the Greek word *soma* meaning body.

self-possessed personality, and unconflicting emotions and is descriptive of a vigorous mind in harmony and at peace with itself. Among the symptoms of mental health are feeling, thinking, willing, happiness, contentment, satisfaction, cheerfulness, interest, energy, activity, persistence, perseverance, fearlessness, and courage.

Social health.—The social health of an individual is his ability to adjust himself to his social environment. The socially healthy individual adapts himself to the folkways and mores of his group and the beliefs and customs of his society. His personality and behavior do not conflict fundamentally with those of his people. The symptoms of social health in an individual are friendliness, altruism, co-operation, teamwork, loyalty, honesty, love, sociability, sportsmanship, honor, leadership, and dependability. The signs of social health include participation in group life, play, athletics, business association, community service, humanitarian programs, marriage, home building, and parenthood.

Interdependence of somatic, mental, and social health.—It is convenient for purposes of description and discussion and for better understanding to separate health into these three major parts. Naturally, however, human health must include all three. No one of these types of health can exist alone. Somatic health, or mental health, or social health may be the dominating achievement in the life of a given individual, but each of the other two must be present in some degree in order that the one be conspicuously achieved.

Signs of disease.—A brief description of disease, a reference to the signs of disease, and a definition of disease are in place here because of the better understanding such information will give to our definitions of health and of hygiene. The topic is more fully treated in "Principles of Defensive Hygiene," the second part of this book.

Signs of disease are displayed in disturbances of growth, development, maintenance, co-ordination, function, government, adaptation, comfort, and ease. The word "dis-ease" is a very old word. It was probably invented slowly in a bygone age when mankind first noted, remembered, and compared the differences between "ease" and "dis-ease." We may guess that the invention of this word was stimulated by pain and based on an appreciation of comfort. Now after these many thousands of years of experience, we understand health as a normal, structural, and functional

condition characterized by a somatic, mental, and social state of ease; and similarly we understand disease as a subnormal, or abnormal, structural or functional state characterized sooner or later by disturbance of some detail of somatic, mental, or social ease. Thus we have diseases that are mainly somatic (physical, bodily, or organic), or mainly mental, or mainly social. A broken leg, a black eye, a boil, appendicitis, and pneumonia are samples of diseases that are mainly somatic. Worry, anxiety, remorse, fear, and the signs and symptoms of such diseases as "shell shock" (the psychoneuroses), feeble-mindedness, and epilepsy are some of the evidences of diseases that are mainly mental. Social maladjustments, anti-social behaviors (selfishness, greed, envy, jealousy, suspicion, anger, rage, dishonesty, etc.), and insanity with suicidal or homicidal tendencies belong in the category of social diseases and are signs of social diseases.

Definition of hygiene.—The preceding definitions of principles and practices and of somatic, mental, and social health and disease establish the definition of hygiene as the principles and practices that ultimately determine and regulate the production, improvement, maintenance, protection, and defense of somatic, mental, and social health and the prevention of somatic, mental, and social disease. Hygiene is thus necessarily a combination of somatic hygiene, mental hygiene, and the hygiene of social personality.

The construction and defense of health is a complex process that is fundamentally physiological. On the one hand, it is self-regulating or self-governing, mechanistic, and inevitable. On the other hand, the construction and defense of health is determined by the voluntaristic behavior of the individual in relation to his environment.

We shall describe self-governing, self-regulating, mechanistic, inevitable hygiene as autonomic hygiene. We shall describe the government or regulation of health by the witting (the contrary of unwitting), calculated planning of the individual as voluntaristic hygiene. Thus ideally voluntaristic hygiene is the art and science of preserving health. As a matter of tragic fact, voluntaristic hygiene is too often superstitious and empirical. Autonomic hygiene is the self-governing determination and regulation of somatic, mental, and social health by means of the sequences of cause and effect that under given conditions unalterably tend

to produce, maintain, defend, or restore health, or prevent disease, regardless of the ignorance, knowledge, interest, or indifference of the individual concerned.

Autonomic hygiene.—The preservation of the health and life of an individual depends upon the operation of certain physiological processes. Those processes are self-regulating and independent of the consciousness, information, or will of the individual. Thus they are autonomic. The same dependence upon the self-regulating physiological relations between cause and effect obviously governs the health and the life of every living animal and every living plant.

Some of the more important examples of the constructive and defensive biological self-governments that constitute what we are describing here as autonomic hygiene are found in the physiological regulations that govern reproduction, heredity, nutrition, growth, development, maintenance, the coagulation of the blood, inflammation and repair, and the immunity reactions. This autonomic government produces and regulates cell-division (mitosis and meiosis), fertilization, reproduction, the physical-chemical reactions of tissue-cell metabolism and function, the tropisms, unconditioned reflexes, and instinct behaviors.

Autonomic hygiene is a heritage common to all forms of life, plant and animal. It is the only hygiene possible in the absence of intelligent mind.

Voluntaristic hygiene.—Voluntaristic hygiene is the witting attempt to preserve health. Voluntaristic hygiene is possible only as a concern of intelligent mind. The health preservation of plants is a product of their autonomic hygiene. As long as favorable environment obtains, the plant grows, develops, leads its life, produces its offspring, and dies in what we believe to be its normal way. But the arrival of excessive heat or cold, drought, exhaustion of food supply, enemy parasites, plant-eating animals, or destructive man may bring death or disease against which the plant has no adequate defense, certainly no voluntaristic defense.

On the other hand, we know that the intelligence of man has supplied an enormous influence for the preservation (constructive and defensive hygiene) of plant life. The plant has no voluntaristic hygiene of its own any more than has the unborn babe or the infant. The orange tree has no adequate defense against the unseasonable frost. The Mediterranean fruit fly, the boll weevil,

the corn borer, and other enemies of plant life are controlled—if controlled at all—by the intelligence of man and by external nature, not by any resource in the volition of the plant itself.

The health preservation of animals is largely autonomic. It is debatable where in the scale of animal life intelligent mind appears. But there is no question that the maintenance and defense of health and life of animals is largely, if not wholly, a matter of self-regulating physiology which we are describing here as autonomic hygiene. The phenomena of instinctive hygiene are universal in the world of animals. The preservation of animal life throughout the ages is a product of their self-regulating constructive and defensive physiology (autonomic hygiene) acting in the presence of essential favorable environment.

Finally, it is obvious that the preservation of human health and human life among the ancient and modern savage, barbarous, and primitive peoples and among our modern illiterate, ignorant, and helpless human beings is the joint product of human autonomic hygiene and favorable environment.

Voluntaristic hygiene is the witting effort to preserve health, that is to say, to maintain, improve, defend, or restore health. We may safely guess that voluntaristic hygiene began with the appearance of intelligent mind and that human voluntaristic hygiene began when mankind appeared in the world. The applications of intelligence to problems of hunger and thirst, of heat and cold, of escape and defense, of ease and discomfort (i.e., dis-ease), of satisfaction and dissatisfaction has constituted the voluntaristic hygiene of mankind from the beginning.

When man invented spoken language, its greatest use, perhaps its only use, was for purposes that we describe here as purposes of constructive and defensive hygiene. The invention of written language was probably stimulated by the demands of barter, trade, convenience, and war, all of which are concerned more or less directly with the preservation of health. Spoken and written language were produced by mankind for the control of favorable environment.

Autonomic hygiene is the same today as it was when life began, whenever that may have been; but voluntaristic hygiene has changed with the accumulation of information and knowledge, that is to say, with the advance in the education of human intelligence. The first voluntaristic hygiene was empirical. It was

built up out of experience by the individual, the group, or the tribe. The folkways and mores, the beliefs, and customs of early mankind were largely, if not wholly, concerned with the satisfaction of their pressing requirements for the preservation of health and life. They constituted the voluntaristic constructive and defensive hygiene of our ancestors. We describe their hygiene today as empiricism, superstition, magic, taboo, religion, primitive medicine, and the beginnings of science.

Voluntaristic hygiene was a part of the wisdom of the Egyptians thirty-five hundred years ago. A temple to the goddess Hygeia was erected by the Greeks more than twenty-five hundred years ago. The writings of Moses codified the hygiene known to the Children of Israel. Hippocrates wrote a "treatise on airs, waters, and places" over twenty-three hundred years ago and recorded in perpetuity certain valuable information that was even then at least a thousand years old. Over seven hundred years ago the Code of Health from the School of Salernum (A.D. 1200) assembled many facts on hygiene that are in harmony with modern scientific information. The Code passed through more than two hundred editions and "for over two hundred years it appears to have been the most popular book in existence." Hygiene is, therefore, an ancient art.

Voluntaristic hygiene today is increasingly scientific. More and more of our knowledge of health and disease is a knowledge of physiology and of the physical, mental, and social influences that affect physiology. This knowledge is scientific and dependable. More and more of our use of that knowledge—the art with which we apply it—is scientific.

Principles of hygiene.—The causes that ultimately determine and regulate the production, improvement, maintenance, defense, and restoration of health constitute the principles of hygiene. They are the principles of somatic hygiene, of mental hygiene, and of wholesome social personality. Thus we have scientific information that we describe here as principles of (1) constructive hygiene, because that information is concerned with the construction or production and maintenance of health; (2) defensive hygiene, because it has to do with the protection and defense of health and the prevention of disease; and (3) remedial hygiene, which relates to the restoration of health. This book is concerned with constructive hygiene and defensive hygiene. Remedial hygiene

includes the subject matter of medicine, and is not covered in this series of texts.

Principles of constructive hygiene.—We have defined constructive hygiene above as being concerned with the sequences of cause and effect that construct health. Any influence that produces, improves, or maintains health belongs to constructive hygiene Thus the subject matter of constructive hygiene includes reproduction and heredity and the experience of heritage with nutrition, excretion, exercise (use), rest, and external physical, chemical, biological, and social environment. Constructive hygiene is somatic, mental, and social and it is autonomic and voluntaristic. The appropriateness of describing these influences as constructive causes of health may be proved by the following very brief descriptions.

1. *Reproduction.*—The physiological events that unite a healthy sperm-cell with a healthy ovum are essential to the production of the single cell with which a human life begins. The physiological influences that divide that single cell (a fertilized ovum), and thus by similar succeeding cell divisions produce an infant, are essential to the reproduction of human life. There is no other way to produce a healthy beginning of a human being. Therefore, reproduction is an essential factor in constructive hygiene.

2. *Heredity.*—The transfer of factors that determine health—the "genes" of health—from parents to offspring is requisite to the production of a heritage of health and the promise of growth and development under the stimulating influences of experience with favorable internal and external environments. Healthy heredities are prerequisite to healthy heritages. Without them there can be no gift of life or health from parents to children.

3. *Nutrition.*—The heritage of microscopic organs, of energies, of patterns of growth and development, and of potentialities that determine life and health contained in the single cell with which a life begins and distributed by the multiple divisions of that cell to its trillions of daughter-cells and to the tissues and organs that those cells form in constructing a living, integrated, thinking, relatively independent man or woman—this remarkable heritage must have a continuously satisfying experience with an adequately constructive and maintaining nutrition if its potentialities of life and health are to be realized. Nutrition is one of the most obvious influences in constructive hygiene.

4. *Excretion.*—The rejections and wastes that arise from the chemical and physical changes that take place in the single living cell or from the multiplying, growing, and manufacturing millions of cells of the living human being must be removed if the production and maintenance of the health of the single cell or of the multitude of cells is to continue.

5. *Exercise.*—From the appropriate use of cells and organs comes improvement in their structure and function. Out of the exercise of organs and their functions comes growth, development, co-ordination, integration, and education of body, mind, and personality. If this usage is a fortunate usage, it helps produce and maintain health. From such activities as appropriate work, physical exercise, and play may come favorable somatic and mental activity and social experience that produce somatic, mental, and social health.

6. *Rest.*—The production and maintenance of health is dependent upon proportionate relaxation, recreation, loafing, inactivity, and sleep.

7. *Environment.*—Favorable experience with favorable external physical, chemical, biological, and social environment is essential to the production and maintenance of somatic, mental, and social health. Such an environment may be furnished by climate, sunshine, housing, clothing, plant life, animal life, family and other group associations, and community organization.

Principles of defensive hygiene.—The relations of cause and effect that protect health and prevent disease constitute the principles of defensive hygiene. These relations may be autonomic or voluntaristic. They have to do with the defensive hygiene of heredity and the defensive hygiene of heritage. The influences that protect good heredity and prevent the transfer of bad heredity and the consequent production of defective heritage constitute the defensive hygiene of heredity. The influences that protect good heritage and prevent its disease (injury, damage) constitute the defensive hygiene of heritage.

The principles of defensive hygiene are thus concerned with the protection of good heredity, the prevention of the transmission of bad heredity, and the protection and defense of healthy heritage. They are concerned, therefore, with the protection of germ-line cells from injuries that may damage the heredities they carry, as in syphilis or by irradiation with X-ray or radium. They are con-

cerned with the prevention of marriages that would transmit such mental deficiencies as feeble-mindedness. This subject is concerned with the prevention of deficiencies or deprivation of nutrition, excretion, exercise (uses that stimulate growth and develop and educate body, mind, and personality), and rest. It is concerned with the prevention of injuries from unfavorable environments, namely: (*a*) unfavorable physical environments, such as adverse climate, inclement weather, insufficient clothing, bad housing, lack of sunshine, extremes of heat or cold, dust, noise, smoke, loose commercial electricity, the mechanical causes of injury (bruises, lacerations, fractures, crushings, and concussions) in automobile, industrial, and domestic accidents and in the casualties of war; (*b*) unfavorable chemical environments, as carbon monoxide poisoning, illuminating gas, alcoholism, drug addiction, lead poisoning, and in unsafeguarded chemical manufactories; (*c*) unfavorable biological environments, such as may be furnished by deficient supply of food plants, food animals or foods derived from plants or animals; by poisonous vegetation; the plant germs (bacteria) that cause disease; predatory animals, poisonous snakes, and insects; the animal germs (protozoa) that cause disease, and the animal and insect carriers of disease germs; (*d*) adverse social environments that lead to social maladjustments, emotional conflicts, and anti-social behaviors, such as poverty, illiteracy, ignorance, greed, selfishness, and war.

The practice of individual hygiene.—Individual hygiene may be described as the application of the scientific facts of general constructive and defensive hygiene by the individual for his own health welfare. Individual hygiene is voluntaristic. It is largely confined to the mature individual. The personal hygiene of infants, children, and other dependents is established wittingly or unwittingly through parents, guardians, teachers, or others on whom they are dependent. The health welfare of dependents belongs to the fields of group and intergroup hygiene.

The practice of group hygiene.—Every individual belongs to or has been a member of a family group. At one time or another he is associated with a school group or an occupational group. He belongs to a play group, a "gang," a recreational group. He is a member of an athletic squad, a club, a fraternal organization. Whenever he associates with one or more other persons he is for the moment a member of the group which he and they form. The

individual spends his life as a member of the various groups that constitute his social organization.

The group is probably the most important factor in the production, maintenance, and defense of human health. The continuity of the human race, the preservation of the life of the individual, and the maintenance and defense of the health of the individual are wholly dependent and have always been dependent upon the hygiene of the family group into which he was born or of some equivalent group that took over the family functions after his birth. The maintenance of health and life and the defense of health and life of the individual depend upon the constructive and defensive hygiene of the groups with which he lives, serves, plays, achieves his education, works, loafs, rests, recreates, or otherwise spends his time.

The practice of scientific group hygiene may be defined as the application of the proved principles of hygiene by groups of people for the health welfare of their members. The practice of scientific group hygiene is in contrast with the practices that are based on superstition and empiricism. The members of such groups, responsible and dependent, competent and incompetent, mature and immature, are associated more or less intimately with each other for periods of time. They live under common environmental influences and common hygienic advantages and disadvantages. The adult competent members of the group are under common health responsibilities.

The practice of intergroup (or societal) hygiene.—Historic experience demonstrates that the single group cannot effectively provide the power and resources necessary to maintain and defend the health and life of its members. The beginnings of human society were formed long ago when family groups first associated with each other irregularly or permanently for the advantages of a mutual defense against their common enemies, for success in securing food, or for some other satisfaction essential to health and life. The same necessities of hygiene that produced the first villages, the first clans and tribes, the first nations, and the first federations or confederations are responsible for the associations of groups that today constitute our societal communities. These intergroup organizations form our political entities, such as our village and municipal governments, our town, county, state, and national governments, and our international leagues.

The practice of scientific intergroup hygiene (i.e., societal hygiene) may be defined as the application of the proved principles of hygiene by the public for the health welfare of the public. The intergroup idea conceives society (i.e., the public) to be made up of associated groups of human beings, dominated by common health interests, exposed to common health dangers, and competent to enact laws and make appropriations and to establish and enforce common standards of individual and group responsibility for community and public health. The political autonomies involved are such entities as the rural community, the village and city, the town or township, the county, the state, the nation, and the alliance of nations. Intergroup hygiene is dependent upon public opinion, and on public action. It has a distinctive legal basis in the ordinances, laws, and enactments of political autonomies.

Importance of health.—Health is the product of hygiene. In the presence of favorable environment autonomic hygiene produces and preserves good health. With unfavorable environment, autonomic hygiene fails. The promotion, maintenance, and defense of health then depend upon the scientific quality and wisdom of the voluntaristic hygiene that is practiced by the community, the family, and the individual.

Normal health is more than a physical ability to eat, sleep, and get about. It is more than an absence of excessive temperature, rapid or irregular pulse, rapid respiration, or bodily pain. We must think of health in relation to the mind and the emotions and instincts and not separately as a state of the body alone in which the mind does not participate. Complete health is mental, spiritual, and social, as well as physical. It is a matter of intelligent happiness as well as of gross comfort. It is a matter of getting along smoothly with your family, your group, and your community as well as getting along comfortably and without conflict with yourself.

The presence of health is not proved by ability to get up in the morning, eat three meals, and get through the day without a temperature. The danger signals of disease are very important. But the absence of obvious danger signals does not guarantee an absence of danger, nor is it an assurance of health.

Good, active, complete, aggressive health is the most important thing in the world. If you would learn something of the value of health, ask the man who has lost it. Go to the woman who is

trying to buy it back. Talk with the wife and children of the invalided workman. Visit the clinic, the hospital, the reformatory, the asylum, and the jail and see what poor physical health, poor mental health, and poor social health have done to injure men, women, and children.

Good health is the quality of your physiology that gives you normal growth, normal development, and normal function. It is a state of body and of mind that makes it harder for you to be sick and easier for you to get well. It is a spiritual, mental, physical, and social condition that brings a sense of comfort and well-being and an enthusiasm for the day's work. It is the thing that removes the fatigue of yesterday, restores energy for today, and makes ready for tomorrow. It is a cause and an effect of happiness. Complete health is the basis of real happiness and makes for a fuller measure of success in life's work, whatever that work may be.

CHAPTER II

THE BIOLOGICAL ORIGIN OF THE PRINCIPLES AND PRACTICE OF HYGIENE

Preview of chapter.—We have noted on previous pages that the principles of hygiene are the causes that ultimately determine and regulate the production, improvement, maintenance, defense, and protection of health and life, and that the practices of hygiene are the behaviors of individuals, groups, and societies that are forced or persuaded because of those principles. This chapter records proof that the principles and practices of hygiene originate in the biology of the protoplasmic cell and that the health and life of the individual are: first, products of the favorable health heritage of his tissue cells received by them in the heredity transmitted to them by his parents; second, the health and life of the individual are products of the favorable environment of his tissue cells; and, third, his health and life are products of the favorable experience of his tissue cells with that favorable environment. This chapter will record further the facts (1) that the individual is an essential environment and must maintain an essential environment for his tissue cells; (2) that the family group and other groups are essential environments and must furnish essential environments for the groups and individuals of which they are composed; and (3) that the individual, the family, and society are forced into existence by and for the satisfaction of the biological requirements of the human tissue cell. There is no other way.

Invention of the microscope.—The researches that revealed and proved the cellular structure of all living things were made possible by the discovery of the magnifying properties of transparent curved surfaces and the consequent but very long-delayed invention and perfection of the microscope.[1] Prior to the microscope, the protoplasmic cell was a part of an invisible and unknown living world.

The date of the discovery of the properties of magnification shown by convex lenses and other transparent curved surfaces is

[1] See William A. Locy, *The Growth of Biology* (Henry Holt & Company, 1925), chap. xi, "Primitive Microscopes and the Discovery of Micro-organisms"; S. G. Blanchard, Stubbs, and E. W. Bligh, *Sixty Centuries of Health and Physick* (Paul Hoeber, 1931), chap. xiii, "The Microscope and the Discovery of Germs."

not known. A lens-shaped rock-crystal ornament was found by Layard in the ruins of Nineveh and may be seen in the British Museum. It was thought for a time that this crystal was a double convex lens, but expert examinations show that its surface is faceted and that it therefore could not have been used for purposes of magnification. Greek and Roman writings refer to burning-glasses. Seneca (A.D. 63) states that small letters are larger when viewed through glass globes filled with water. It is thought by some authorities that the perfect cutting of precious stones done by the ancients was not possible without the aid of magnifying lenses. This is questioned by others. An Arabian physician, Alhazen, wrote in A.D. 1052 an account of the human eye and recorded a knowledge of optics including the magnifying properties of convex lenses. He made a simple microscope. The use of spectacles in Europe as early as the thirteenth century is a matter of historical record.

We do not know when the phenomena of magnification by means of convex lenses and other transparent curved surfaces were first observed. Nor do we know when these properties were first applied to the examination of structures too small to be seen by the unaided eye. We do know that magnifying glasses and simple microscopes came into use for the study of minute objects during the latter part of the sixteenth century. An Englishman by the name of Digges in 1571 and a Hollander, Zacharias Jansen, in 1590 were among the earliest and most prominent inventors of microscopes.

The invention of the microscope was a necessary precursor of its use for scientific purposes. But the discovery of the research value of the microscope and the formulation and adoption of methods of precision in its use were achievements of the greatest importance. The name of the great astronomer, Galileo, is prominently associated with the early use of the microscope for scientific purposes. He made his first telescope about 1608. In 1609 he published results of microscopic examinations that he had made of small objects.[1]

Athanasius Kircher, a monk, is said to be the first investigator to publish observations on living organisms visible only with the aid of the microscope. His work appeared in 1646. He saw and

[1] Locy, *op. cit.*, p. 198.

described living things, which he called "worms," in decaying matter, in milk, and in the blood of people sick with fevers. The claims in favor of Kircher are disputed, notably by Clifford Dobell in his book on van Leeuwenhoek and his "little animals."

Anton van Leeuwenhoek of Holland (1632–1723) is the best known of those early observers of the microscopic world. If not the first, he was one of the first to grind and polish lenses with sufficient perfection to make the simple microscope really serviceable for the examination of objects too small to be seen by the naked eye. Van Leeuwenhoek made several hundred microscopes. His simple microscopes were crude compared with our

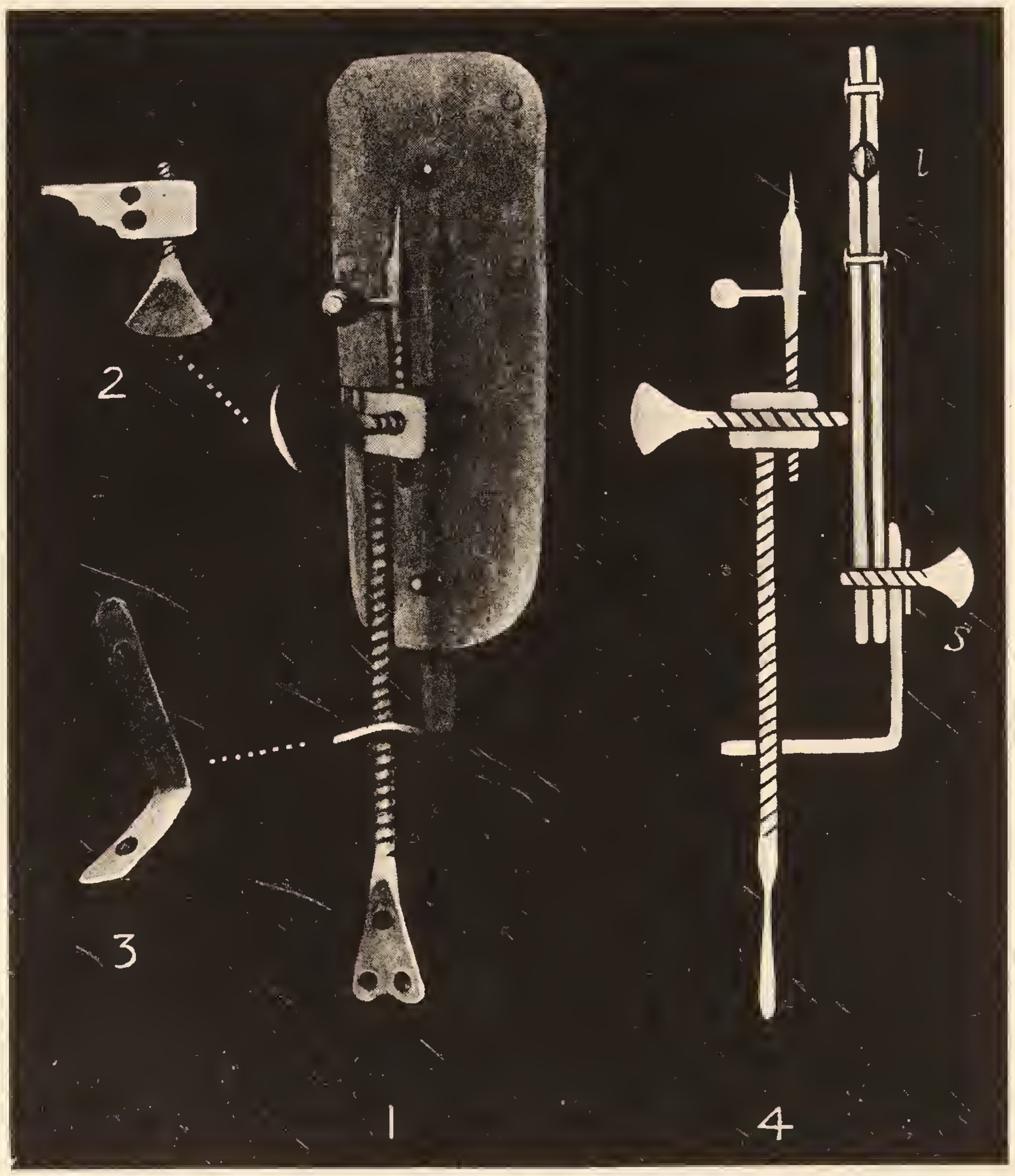


FIG. 2.—Leeuwenhoek's "microscope," from Clifford Dobell, *Anthony van Leeuwenhoek and His "Little Animals"* (Harcourt Brace & Company, 1932), (see description on pp. 327–29) : 1, the whole "microscope"; 2, thumb-screw control, shown also in 1 and 4; 3, detail for support and control; 4, diagram of side view of "microscope" showing biconvex lens at *l* and a second thumb-screw control at *S*. The observer placed his eye before the lens at *l* viewing an object on the rod point just behind the lens on a level with his line of vision through the lens.

instruments today, but they were the best of his time and the best that the world had then ever produced (see Fig. 2). His records of the things he saw are of surpassing interest, for he was the first man who had ever seen many of the microscopic plants and animals that we have since investigated with patient scientific care.

The compound microscope generally consists of two systems of positive lenses arranged for greater magnification. The first makers of compound microscopes seem to have been Johann and Zacharias Jansen, lens-grinders in Middelburg about 1590. William Robert Hooke in 1667 improved the compound microscope. To him is credited the discovery of the cell. Yet the simple microscope was a more useful instrument than the compound microscope of that time. It was then the general opinion that the compound microscope could not be made practical.

Kircher, van Leeuwenhoek, Hooke, and their followers made improvements that surpassed all that had been made in the construction and manipulation of magnifying lenses in the preceding centuries. But their improvements were insufficient. Their microscopes brought to them a world filled with unnumbered living "animalcula" of strange and wonderful appearance and habits. They were admitted to regions that had never before been seen by human eyes. But their microscopes gave them pictures only of what might be called the gross microscopic structure of plants and animals. The finer structures of plant and animal tissues were beyond the reach of their crude low-power instruments. The microscope had discovered a new world, but the finer details of that world were still hidden from human vision.

The modern microscope.—It was almost two hundred years later that the era of greatest improvement in the microscope arrived and with it the era of most important microscopic discoveries. Prior to 1830 the magnification and resolving power of the microscopes that had been invented were insufficient to enable the investigator to see minute plant and animal structures and thus search the cell successfully for the information on which biology is based. The illumination of objects during microscopic examination was poor. The lenses distorted the images they produced and surrounded them with fringes of color due to spherical aberration, chromatic aberration, and astigmatic effects. The manipulation of the object for examination or during examination was exceedingly cumbersome. The limitations of those crude microscopes

and their crude and meager accessories made research under high-power magnification impossible.

The modern microscope is a product of improvements made since 1830. Its present perfection was achieved only near the end of the nineteenth century. These improvements are commonplace today. Their importance to the progress of the biological sciences and of all investigations of microscopic structures is largely forgotten. The more significant of these improvements are: (1) the achromatic lens system; (2) water and oil immersion lenses; (3) the apochromatic objective; (4) the compensation eye-piece; (5) substage illumination and the Abbé condenser; (6) the control of focus with micro-millimeter screws; and (7) the mechanical stage. The microscope of today gives a magnification up to 2,500 to 3,000 diameters with clear definition. Greater increase is accompanied by blurring. The mechanism of the human eye cannot take care of greater magnification.[1]

Thus the improvements in the microscope in the seventeenth century and the later and more important perfections of the nineteenth century have made possible the discovery not only of a world of otherwise invisible and therefore unknowable plants and animals but also of an otherwise invisible and therefore unknowable world of animal and plant cells, cell structures, cell details, and cell events.

Laboratory technique.—But the service of the modern microscope in the advance of scientific knowledge is a service made possible only by the development of ingenious and remarkable laboratory methods, laboratory accessories, and laboratory techniques. The varied devices and procedures now used for the preparation of specimens, their fixation, hardening, sectioning, mounting, and staining for microscopic examination, are examples

[1] The measurements of microscopic dimensions are usually recorded in microns. One micron is one one-thousandth of a millimeter. The symbol of the micron is the Greek letter μ. $1\ \mu = 0.001$ mm. A sub-micron is one one-thousandth of a micron or one one-millionth of a millimeter. The human eye is incapable of forming images of points that are separated by less than one-half a wave-length of light. The wave-length of light in the visible spectrum is between 450 and 760 sub-microns. Therefore, points that are less than 200 sub-microns apart cannot be focused on the retina of the eye and are beyond the resolving power of the microscope. The ultramicroscope detects the presence of particles that are beyond the reach of the ordinary microscope because the ultramicroscope brings into microscopic view the diffraction images produced by these ultramicroscopic particles under powerful reflected light.

of one great group of contributions to laboratory resources that have been made by hundreds of investigators, whose successful scientific achievements have been due in large part to their brilliant ingenuities and original techniques. They, too, have been inventors. Other such groups of contributions essential to successful microscopic research might be mentioned.

Scientific progress.—The student of today, acquiring the outstanding facts in the accumulated information which society has made available to him in the college and the university, can with difficulty appreciate the enormous amount of patient research that has produced this information. He often is wholly unaware of the complicated and extensive contributory researches and experiences that, extending through long series of years and built up by the investigating labors, the discoveries, and the ingenious inventions of many men and women, have furnished the perfections of each single mechanical device or of each factor in technique among all the devices and techniques that in combination made it possible to prove the truth of the information before him. The manufacture of glass and the grinding of lenses have a very ancient history. Perfect, or approximately perfect, "optical glass" for microscopic service has been produced only within the last fifty years. The brass in the tube of the microscope is a product of such human experience. The micro-millimeter screw regulating the focus of the oil-immersion lens represents the composite intelligence of many minds, including those that by slow and painful learning made the metal and those whose equally slow and painful learning devised the many discarded methods that finally led up to the best we have today for making micro-millimeter threads.

One may easily overlook the immense importance of the remarkable progress that has been made in recent years in our knowledge of physics and chemistry and in the use of that knowledge for the study of the cell and of organisms, all of which are made of cells. This importance is responsible for a great scientific literature and for texts and university courses under the titles of biophysics (the physics of biology) and biochemistry (the chemistry of biology). The study of the cell with the aid of physics, chemistry, and the microscope has led to the appearance of the word "cytology" and to the production of a mass of scientific publications on cytology.

The prepared research mind.—It is clear that the search in the cell for the solution of biological problems is a search that has been made possible because of the prepared service of much high-grade human intelligence in the field of research. A proved fact that has become an outstanding and convincing contribution to our knowledge of the cell or of the part it plays in biology is nearly always associated with the names of the investigators immediately responsible for the first announcements of the fact. But the discoverer of a fact is practically always dependent upon his predecessors and associates. He has been able to carry the progress of others to a point or stage of more obvious settlement and conclusion. He or his associates receive merited credit for their services to society, and the very essential contributions of their predecessors are easily overlooked.

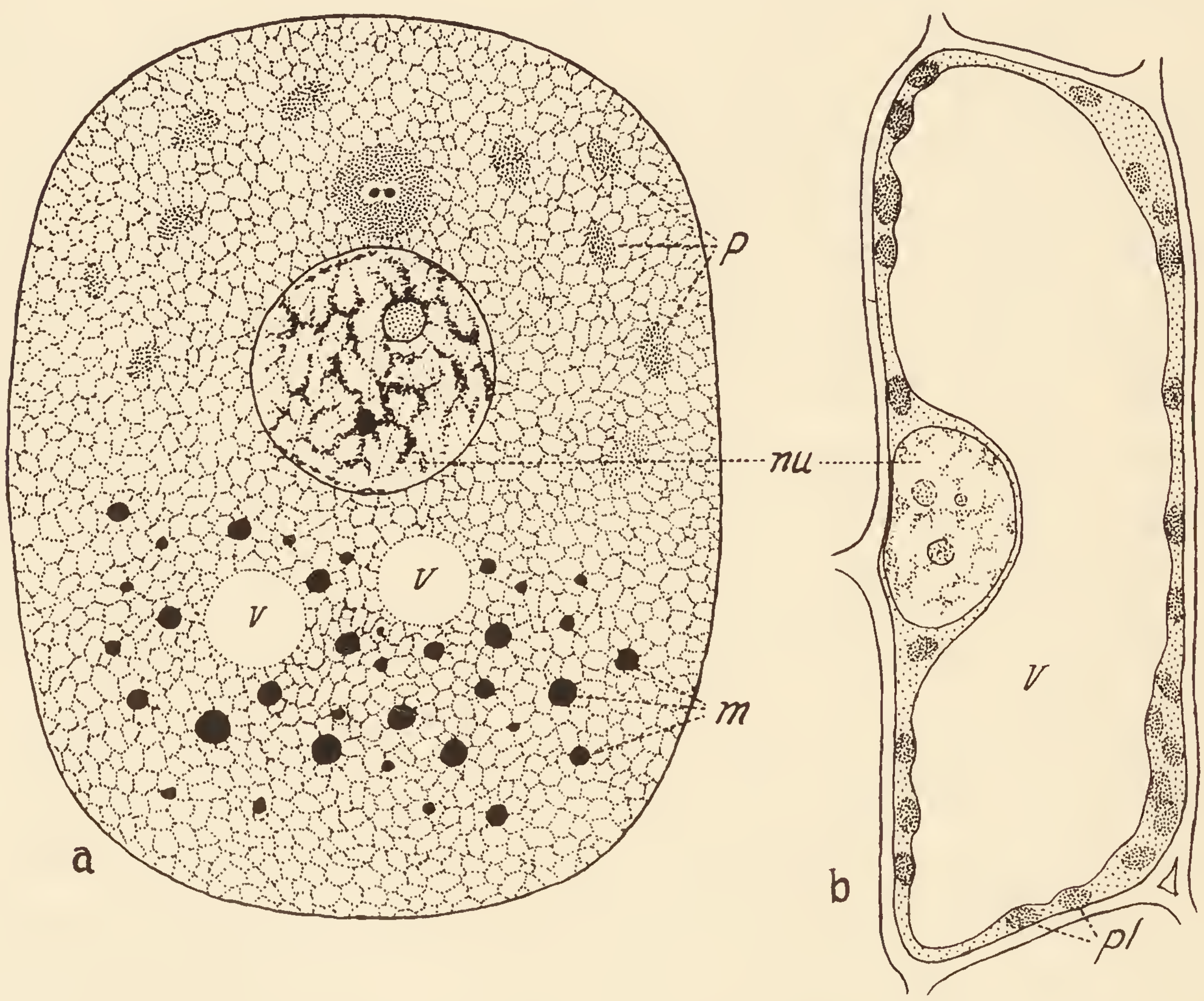


FIG. 4.—Typical protoplasmic cells: *a,* animal cell (after Wilson); *b,* plant cell (after Smith). The cell membrane surrounds *a.* In *b,* the cell membrane surrounds the protoplasm represented in the figure as containing the nucleus and the chromoplasts. The outer lines of *b* are boundaries of the non-living woody wall which encloses each cell. *m,* lifeless material, food, secretions, wastes, etc.; *nu,* nucleus; *p,* plastids, living self-perpetuating organs of unknown functions; *pl,* chromoplast containing a pigment chlorophyl; *v,* vacuole.

Discovery of the protoplasmic cell.—It is common practice today to use the term "protoplasmic cell" or simply the word "cell" to identify the microscopic bit of living protoplasm containing a nucleus that we now know is the "vital unit" with which all living things—plants and animals—are constructed (see Fig. 1 [frontispiece] and Fig. 4).[1] The discovery of the protoplasmic cell was made in three stages during a period that lasted for the greater part of two hundred years following the first observations of "little animals" by van Leeuwenhoek in the seventeenth century. These stages were: (1) the discovery of the wall of the cell; (2) the discovery of the nucleus of the cell; and (3) the discovery of the protoplasmic structure of the cell.

In his thrilling adventures into the then unknown world of microscopic organisms that he, with his magnifying lenses, was the first man ever to see,[2] Leeuwenhoek described "animalculi" (little animals) that we now classify as one-celled animals (protozoa), one-celled plants (protophyta), or one-celled organisms that may be plants or animals (protista). In addition, among the many microscopic forms reported by Leeuwenhoek in his letters to the Royal Society in London are his descriptions of: "little animals of the smallest sort . . . . the smallest sort of animalcules . . . . more than 110 million . . . . [making a mass] as big as a grain of sand," that were evidently bacteria; "seminal animalcules," that we now classify as sperm cells; and "blood globules," the red blood cells. In addition he observed the tissues of various plants and animals, noting their magnified structural details.

Thus, if we except the debated observations of Kircher, Leeuwenhoek was the discoverer of minute forms of life and of microscopic details of plant and animal tissues to which afterward the word "cell" was applied in morphological and structural description.

Stage one: discovery of the cell wall.—The word "cell" was first used to describe the structure of living things by Robert Hooke (1635–1703), a contemporary of Leeuwenhoek. In 1665 Hooke published a book under the title of *Micrographia: or Some Physiological Descriptions of Minute Bodies Made by Magni-*

[1] Figure 3 has been omitted from this edition.

[2] Clifford Dobell, *Anthony van Leeuwenhoek and His "Little Animals"* (Harcourt, Brace & Company, 1932). Dobell challenges the priority of Athanasius Kircher as an observer of microscopic organisms.

fying Glasses, with Observations and Inquiries Thereon. This book carries a drawing and a description of the appearance of a very thin slice of cork as viewed by Hooke through his magnifying lenses. He used the words "pores," "like honey comb," "boxes," and "cells" in this description of the structure of cork. The word "cell" satisfied him better than the other terms. Other observers, notably Malpighi (1674) and Grew (1682), following his lead, adopted the word "cell" in their descriptions of the structures of plants.

The cells that these early investigators saw were mature plant cells (see Fig. 7, p. 33). They saw them as walls surrounding spaces, cell walls containing vacuoles. The spaces contained fluid. The older plant cells are vacuolated. This conception of the plant cell, based on the microscopic appearance of elder plant cells, dominated the minds of research students up to the third decade of the nineteenth century. The cell wall was believed to be the vital and important part of the cell. It was mistaken for the cell as we now know it.

Stage two: discovery of the nucleus.—The determining importance of the cell was not discovered until the end of the first third of the nineteenth century. Then with the aid of the much improved compound microscope and its important accessories, the "prepared minds" of many scientific explorers led to the discovery of the nucleus and to the accumulation of compelling evidences of its dominion over the life of the plant and the animal cell. The nucleus was discovered by Robert Brown in 1831, but its importance escaped his attention. Matthias Jacob Schleiden in his *Beiträge zur Phytogenesis* (1838) presented a wealth of material and formulated a "definite cell theory for plants." Despite Schleiden's erroneous views as to the origin of cells (he believed they were formed de novo) and despite his self-conceit that led him to ignore or discredit the work of most other investigators, his contribution constituted an epochal influence. He completed the discovery that the plant cell with its all-important nucleus is the essential structural unit of all plants. Following Schleiden and stimulated by his brilliant conception, Theodore Schwann, in 1839, in a series of publications announced the discovery of the determining importance of the cell and its dominating nucleus in all animal structures. Schwann's researches extended the cell theory to animals.

But the cell of Schleiden and Schwann was supposed by them to arise because of a "crystallization" of a "mother liquor" or "cytoblastema." The cell as they knew it was a "vesicle" composed of a living wall surrounding a fluid content.

Stage three: discovery of cell protoplasm.—The discovery that the cell is a bit of living substance, to which the term "protoplasm" has been applied, and that every cell comes from a pre-existing cell completed the discovery of the protoplasmic cell. Schleiden described a granular content in plant cells which he designated as "plant slime." Purkinje in 1840 applied the word "protoplasm" to the formative substance of animal embryos in their very early stages of development. Hugo von Mohl in 1846 gave the name "protoplasm" to the "plant slime" of Schleiden. Von Mohl's published work shows that the young plant cell is always completely filled with protoplasm and that the gradual appearance of vacuoles within the cell as it grows older forces the living protoplasm into a peripheral zone lining the inner surface of the cell wall.

Max Schultze is given "credit for having laid the foundation of the modern conception of the cell." Schultze proved that the protoplasm of von Mohl composes the cells of all plants and animals and that the cell wall may be absent and is therefore not an essential structure. He "redefined the 'cell' of Schleiden and Schwann as a 'small mass of protoplasm endowed with the attributes of life' " (1861).[1] Our definition of a cell today is that it is "a small mass of living protoplasm containing a nucleus." During this period the accumulation of facts made it evident that the formation of cells de novo as announced by Schleiden and Schwann does not occur and that cells arise only because of the division (mitosis) of pre-existing cells. The famous aphorism of Virchow (1858), *"Omnis cellula e cellula,"* and that of W. Flemming (1882), *"Omnis nucleus e nucleo,"* are accepted today as proved facts in cytology.

Summary.—In summarizing the stages of the discovery of the protoplasmic cell, it may be said: First, Leeuwenhoek discovered minute organisms and microscopic tissue structures that are now classified as "cells"; Hooke used the term "cell" to describe the cell-like appearance of the mature plant structures that he discov-

[1] See *Encyclopaedia Britannica,* Eleventh Edition, under "Plants."

ered, and his lead in this use of the word "cell" was followed by contemporary and later observers. This was the stage in the discovery of the cell in which the appearance of the cell wall dominated the thoughts of observers. Second, Brown discovered the cell nucleus, Schleiden completed the discovery that the nucleated cell is the structural component of all plants, and Schwann the discovery that it forms the structure of all animals. Together, Schleiden and Schwann completed the discovery that "every living organism is or at some time has been a cell." But both Schleiden and Schwann believed that the cell was a "vesicle" and that its wall controlled the activities of the cell. Third, von Mohl discovered that very young plant cells are not "vesicles," that they contain no vacuoles but are completely filled with a substance that he described by the word "protoplasm." Max Schultze (1861) completed the discovery of the protoplasmic cell when he proved that the protoplasm of von Mohl constitutes the substance of all cells, plant and animal.[1] (See Fig. 4, p. 26.)

[1] The contents of this chapter are patterned largely after the article on "Plants" in the Eleventh Edition of the *Encyclopaedia Britannica,* and chapter xi, "Primitive Miscroscopes . . . . ," in *The Growth of Biology* by W. A. Locy.

CHAPTER III

THE BIOLOGICAL ORIGIN OF THE PRINCIPLES AND PRACTICE OF HYGIENE (CONTINUED)

Study of the protoplasmic cell.—We have noted that the slow discovery of the protoplasmic cell was a product of the observation and careful study of plants and animals by many investigators during a period of some two hundred years. The success of these studies was made possible, as we have indicated above, by the invention, improvement, and perfection of the compound microscope, with its accessories and its associated laboratory techniques; and, perhaps most important of all, by the training and preparation of men's minds for planning scientific research and for the classification, interpretation, and understanding of observed facts. The period from 1830 on, following the perfection of the microscope, completed the startling discovery of the protoplasmic cell and produced an amazing knowledge of the dominating part it plays in determining and regulating the life and health of every living thing—plant, animal, and human.

A few years ago a leading scientist stated: "We have found and described and classified and named about 500,000 living kinds of animals and 250,000 living kinds of plants. There are certainly many more kinds of both animals and plants still to discover and catalog."[1] We have found, classified, and named an enormous number of fossils representing a geological life of many millions of years now extinct. The tissues of every kind of living plant or animal that have been examined by competent observers since the perfection of the microscope reveal their cell structure. Microscopic examination of Devonian sharks fossilized in carbon sixty-five million years ago (or four hundred million years ago according to recent authorities) reveals tissue-cell structures identical with those found on the microscopic examination of similar tissues today.[2] The coal we burn is a product of geological influences brought to bear upon prehistoric vegetation. Microscopic examination of coal reveals its cellular structure. All fossil ani-

[1] Vernon Kellogg, *Evolution* (W. Appleton & Company, New York, 1924), p. 8.

[2] Bashford Dean, "The Preservation of Muscle Fibers in Sharks of the Cleveland Shale," *American Geologist*, 1902, p. 273; also "Studies on Fossil Fishes," *ibid.*, February 1909.

mals and plants on appropriate microscopic examination display their cellular formations. The protoplasmic cell is the structural basis of all plants and animals, living and fossil. It is the vital unit of all living things.

Classification of cells.—All protoplasmic cells may be classified in the following groups.

I. *Plant and animal cells.* The thorough investigations that have been made establish the fact that all protoplasmic cells are either plant cells or animal cells, or they are cells with characteristics common to plants and animals (see Figs. 5, 6, and 7).

1. *Plant cells* form the structure and perform the functions of all plants. All plants are made of a single plant cell or of many plant cells. Every many-celled plant begins its life as a single plant cell. Some many-celled plants are bisexual (male and female). Such plants begin their lives as single cells formed by the union of a male plant cell and a female plant cell, that is to say, by the union of a plant egg-cell and a plant sperm-cell.

2. *Animal cells* form the structure and perform the functions of all animals. All animals are made of a single animal cell or of many animal cells. Every many-celled animal begins its life as a single animal cell. The single cell with which the life of the highest animals begins is formed by the union of an animal egg-cell and an animal sperm-cell.

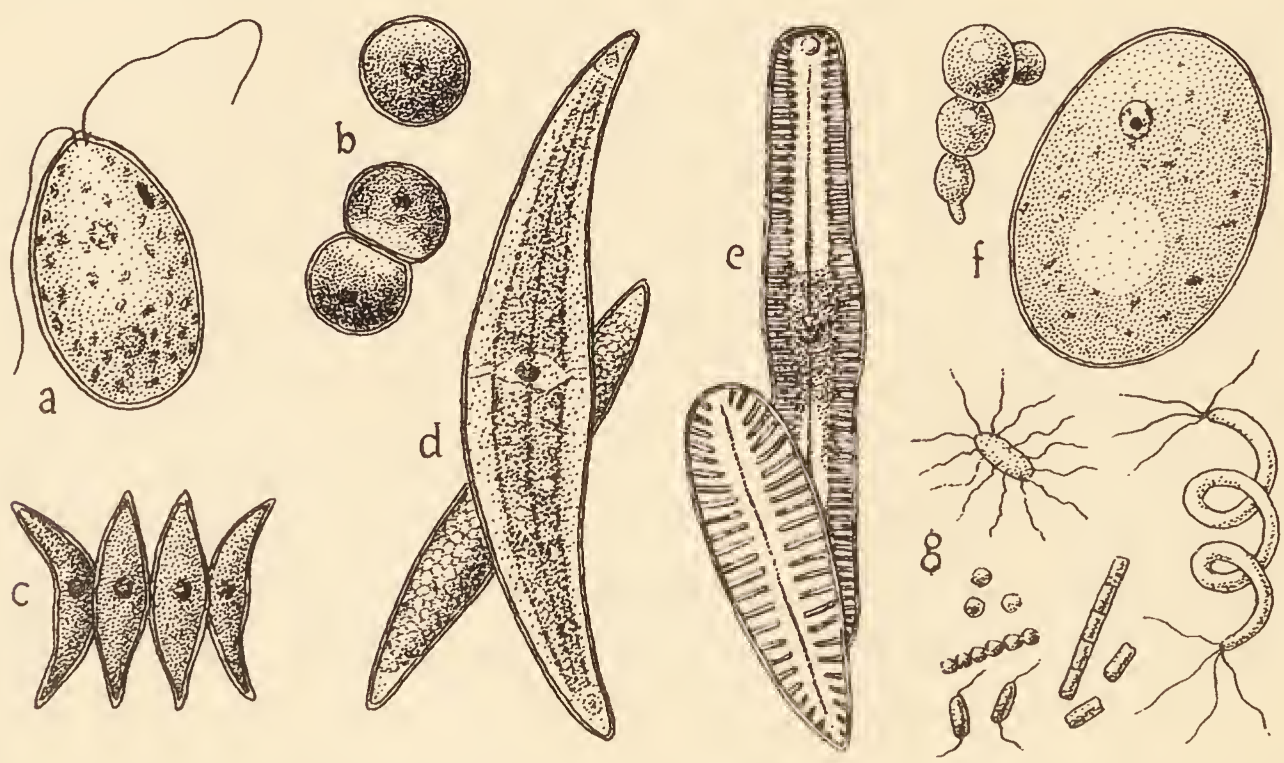


Fig. 5.—One-celled plants, greatly magnified: *a,* Chlamydomonas; *b,* Protococcus; *c,* Scenedesmus; *d,* diatoms; *e,* desmids; *f,* yeast cells, one budding; *g,* bacteria.

FIG. 6.—One-celled animals, greatly magnified.

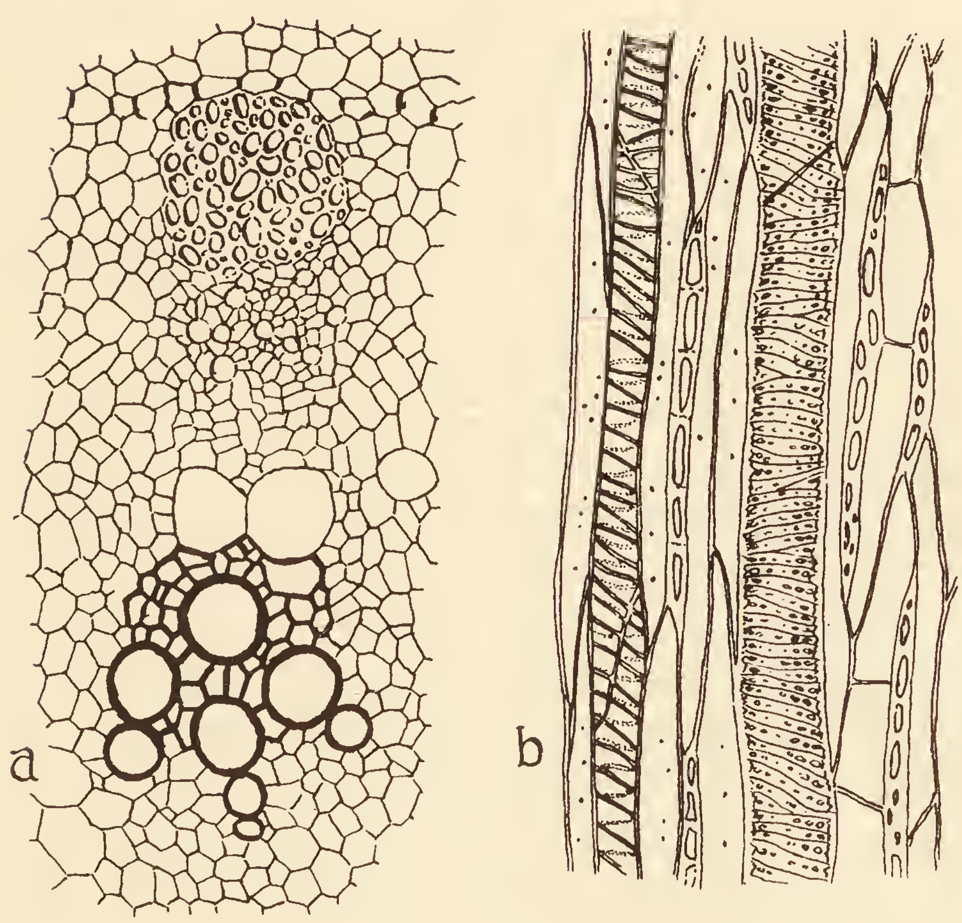


FIG. 7.—Cell structure of plants: *a,* cross section of a portion of a sunflower stem (Coulter); *b,* longitudinal section of the wood of a linden tree (Strasberger).

II. *Protoplasmic cells* that constitute one-celled organisms.

1. *The protophyta* are plant cells each one of which constitutes a whole plant and is a single-celled organism. All the functions of the one-celled plant are performed by the one plant cell of which it is constituted.

2. *The protozoa* are animal cells each one of which constitutes a whole animal and lives its whole life as a single-celled organism. All the functions of such an animal are performed by the one animal cell of which it is constituted.

III. *Protoplasmic cells* that produce, form the structure of, and perform the functions of the many-celled plants and animals.

1. *The metaphyta* are the many-celled plants. Every many-celled plant begins its life as a single plant cell. In many sorts of plants, this single cell is formed by the union of a plant egg-cell and a plant sperm-cell. This union is known as "fertilization" of the egg-cell (or ovum) by the sperm-cell. The egg-cell is then a "fertilized ovum." The fertilized plant ovum is the single protoplasmic plant cell with which the life, growth, and development of certain multicellular plants begin. The living fertilized ovum divides into two cells by a process of simple division known as "mitosis." The processes of mitosis will be described in later paragraphs. The two cells then divide into four, the four into eight, the eight into sixteen, and the multiplication of these cells by this process of simple division (i.e., mitosis) continues thus until a great many plant cells are produced and in sufficient numbers to form the structure and perform all the functions of a mature many-celled plant, a metaphyte.

2. *The metazoa* are the many-celled animals. Every many-celled animal begins its life as a single animal cell. In all the highest animals (e.g., the vertebrates) this single animal cell is formed by the union of an animal egg-cell or ovum with an animal sperm-cell. The fertilized animal ovum, like the fertilized plant ovum, is the single cell with which the life, growth, and development of the highest multicellular animals begin. The repeated divisions of the fertilized animal ovum produce the many cells that furnish the structure and perform all the functions of the animal. By this process, the single fertilized human egg-cell with which the life of a human being begins becomes the four thousand billion living cells that constitute and perform all the functions of a mature man or woman.

IV. *Somatic-line cells and germ-line cells.*

1. *Body-line cells.* In all the many-celled plants and animals, there are protoplasmic cells that are concerned with furnishing structure (anatomy), bodily growth, and development, and with the performance of bodily functions, the physiology of the plant, and the physiology and psychology of the animal. These living cells are known as body-line cells. They construct the tissues and the organs that constitute the body of the individual plant or animal. These cells all eventually die, some during the life of the individual. None of them survives after his death.

2. *Germ-line cells.* Every multicellular plant and animal is constructed in very small part by germ-line cells. These cells are the carriers of the genes and other factors that determine the heredity of plants and animals, and they are the sources of the ova (eggs) or sperms that participate in fertilization and initiate reproduction. The mature female germ-line cell, the ovum, and the mature male germ-line cell, the sperm, uniting, form the fertilized ovum with which the life, growth, and development of multicellular sexual plants and the highest animals including the human being begin.[1] Thus, the germ-line cells have a quality of immortality. Every living body-line cell and every germ-line cell has an unbroken descent from the beginning of life, no matter how many millions of years ago life began and no matter how that beginning occurred. Every body-line cell dies during the life or at the death of the individual of which it is a part. But some, relatively a small few, of the germ-line cells of the plant or animal participate in reproduction and thus continue their "immortality."

V. *Classification of cells according to sex.*

All the protoplasmic cells in the body of a male plant or a male animal are male cells; all cells in the body of a female plant or a female animal are female cells. Certain of the plants and all the higher animals are male or female plants or animals. Sex differences, identifying male and female cells, are shown in the chromosomes of the body-line cells and the germ-line cells of male and female plants and animals. In a later chapter it will be shown that every body-line cell and every germ-line cell of the human male, with the exception of one-half the sperm-cells, contains a Y-chromosome and that no cell of the somatic-line or germ-line cells of

[1] We shall not attempt a discussion of the exceptions constituted by parthenogenesis in certain sorts of plants and animals.

the human female contains a Y-chromosome. (The exception noted for the sperm-cells is based on the fact, to be discussed later, that one-half the human sperm-cells contain Y-chromosomes, and the other half contain X-chromosomes. Every human ovum contains an X-chromosome.)

Summary of classification of protoplasmic cells.—All protoplasmic cells are:

1. Plant cells or animal cells or cells with characteristics common to plants and animals
   a) Protophyta, one-celled plants
   b) Protozoa, one-celled animals
   c) Protista, one-celled organisms with characteristics common to plants and animals
   d) Metaphyta, many-celled plants
   e) Metazoa, many-celled animals
   f) Mankind, composed of animal cells
2. Somatic-line cells or germ-line cells
3. Masculine cells in all male plants and animals, and feminine cells in all female plants and animals

The principles that determine the life and health of the protoplasmic cell.—Today the world possesses an immense scientific literature based on exhaustive studies of the microscopic cellular protoplasmic structure of plants, animals, and mankind; and of the functions and behaviors of protoplasmic cells under all the circumstances under which they are produced, receive the gift of life, maintain vitality and health, grow, develop, serve their biological purposes, transmit heredity, achieve immortality, or die. On these foundations is based our knowledge of the principles that determine the life and health of the protoplasmic cell and of all living things, since all living things are made of protoplasmic cells. This fundamental knowledge has established the fact that heritage, environment, and experience with environment are principles that eventually determine and regulate the production, improvement, maintenance, and defense of the life and health of the protoplasmic cell and therefore of all living things. There are no other ways known to us for the transmission, reception, and maintenance of life and health of protoplasmic cells. So far as we know, there is no living thing that is not made of one or more than one protoplasmic cell and therefore subject to these principles. It then is a

universal fact that the life and health of all living things depend on favorable heritage, favorable environment, and favorable experience with environment.

Heritage of the protoplasmic cell.—A one-celled organism begins its existence as a single cell. Every many-celled organism begins its life as a single cell. The single cell that begins a new life is always produced by the simple division (mitosis) of a preceding cell except as noted below. The preceding cell transmits a heredity to the two new cells formed by its division and each new cell thus receives all its heritage, its heritage of structure and function, from its parent cell.

Structural heritage of the protoplasmic cell.—We have noted that every protoplasmic cell comes from a pre-existing protoplasmic cell. There is one exception to this generalization. This exception is the fertilized ovum with which the life of a multicellular plant or animal begins. The fertilized ovum is always a single cell produced by the union of two cells, an egg-cell and a sperm-cell. With this exception the production of a new cell is always the result of the division of a pre-existing cell into two new cells. This process divides the entire protoplasm of the pre-existing cell into two parts so that each of the two new cells is itself a structural heritage of living protoplasm. The parent cell thus becomes two cells and ceases to exist as a single cell. The structural heritage of a cell is therefore a bit of protoplasm transmitted directly from the parent cell. The form and shape of cells vary greatly. For our purposes we may describe an irregularly globular or cubical shape as typical (see Fig. 4, p. 26). The surface of the cell is known as the "cell membrane." It is a living part of the protoplasm of the cell. The protoplasm, the body of the cell, surrounded by the surface of the cell is known as "cytoplasm." A specialized part of the protoplasm of the cell, known as the nucleus, is ordinarily found located in the central region of the cytoplasm. The nucleus in certain stages of the activity of the cell appears as a globular organ having a surface known as the "nuclear membrane." The nucleus contains a meshwork or reticulum of linin composed of granules that stain characteristically with certain analine dyes. Because of their staining reactions they are called "chromatin granules." This network with its chromatin granules participates very spectacularly and in a most orderly way in the changes that take place in the nucleus during the phases of cell

division (mitosis and meiosis) that will be described below. Other parts of the nucleus, notably the nucleolus, are commonly present. They are not so well understood and need not be considered further here. The cytoplasm contains a number of specialized living structures (organs) that need not be noted here with the exception of the very important astral bodies (or central bodies) that lie on or near the surface of the nucleus. These bodies are sometimes found within the nucleus. Reference will be made later to the part these bodies play in the behavior of the nucleus during mitosis and meiosis. The cytoplasm characteristically contains also nonliving structures of lesser significance to us in our discussion here. Structurally the protoplasmic cell is semifluid, being 70 per cent water. Chemically, the protoplasmic cell contains varying amounts of oxygen, protein compounds, carbohydrates, fats, vitamins, inorganic salts, and water.

A heritage of normal structure is essential to the life and health of the cell. There is ample proof that the protoplasm of the cell, whether it be the cell membrane, the cytoplasm, the nuclear membrane, or the nucleus, is made up of a number of specialized regions or organs that are essential to the maintenance of the life of the cell and essential to its capacity to perform service. The functions of a cell (its activities) are performed by the living organs that constitute the structure of the cell. Obviously the structure (i.e., anatomy) and function (i.e., physiology) of the cell are inseparable. The structure and function (or anatomy and physiology) of living things are therefore inseparable. We separate them for study and discussion and too easily forget that they cannot exist apart.

Functional heritage of the protoplasmic cell.—The normal heritage of the protoplasmic cell furnishes it with all the structural equipment necessary to the performance of the normal activities of the cell. The normal functions of the cell are:

1. Absorption of chemical compounds in watery solution through the surface of the cell. This is a function of the cell membrane and of the protoplasm of the whole cell.

2. Absorption of free oxygen through the cell membrane and probably throughout the whole of the cell protoplasm.

3. Assimilation of chemical solutions by the cytoplasm and the nucleus.

4. Manufacture of the living protoplasm of the cell by the cell.

This is a chemical construction of living cell anatomy by the organs of the cell.

5. Manufacture of special cell products by the organs of the cell. These special products are known as "secretions." Every cell produces secretions. In a multicellular animal, certain cells are specialized for purposes of secretion. In mankind the more obvious of these secretions come from the cells of the mammary glands in the form of milk, from the salivary glands as saliva, from the lachrymal glands as tears. The part played by the secretions of gland cells in the production, maintenance, and defense of life and health is especially convincing and dramatic in the service of the endocrine glands of the human being. The determining influence of the secretions of the endocrine glands—known as "hormones" or "internal secretions"—will be discussed on later pages. It is significant to stress here the fact that every protoplasmic cell produces secretions, whether it be the protoplasmic cell of a one-celled organism or a protoplasmic cell of a many-celled organism.

6. The storage of the products of cell manufacture. The secretions produced by a cell may be stored within the cell, or, as often happens in the case of the multicellular organisms, in the environment of the cell, there available for use in case of need.

7. Transformation of potential energy into kinetic energy. Every living cell builds and stores synthetic chemical compounds whose potential energy may be released on dissociation as heat or work in the accomplishment of the function of the cell.

8. Formation of excretions. Every living protoplasmic cell forms waste products known as excretions. These products may accompany the construction of cell protoplasm or the manufacture of secretions, or they may be formed during the transformation of potential energy into kinetic energy. For instance, all living protoplasmic cells produce carbon dioxide and water as accompaniments of energy transformation producing heat and work.

9. Elimination. All living cells eliminate their secretions and excretions from the nucleus and cytoplasm through the cell surface and discharge them into the cell environment.

10. Mitosis and reproduction. All living protoplasmic cells are produced by a process of cell division known as mitosis. In the one-celled organism this is a process of asexual (i.e., sexless) reproduction and of transmission of heredity. In the many-celled organism, it is a sexual process and in addition a process contribut-

ing to growth and special development because of the increase it produces in the number of cells that constitute the individual it builds. The single fertilized ovum with which the life of a man begins becomes four thousand billion cells because of mitotic divisions that occur in the period of growth between the moment of fertilization and the arrival of maturity. Mitosis in the multicellular organism is, in addition, a process of heredity. Each of the two new cells produced by the division (mitosis) of a single cell is a structural and functional heritage from that single parent cell. Differences in these living heritages interacting with different environments of the cells produce a relatively slow specialization of their descendant cells, forming, thereby, the specialized tissue cells that constitute the growing and adult multicellular plants, animals, or human beings.

The stages and details of mitosis will be discussed on later pages of our text.

11. Meiosis. Sexual reproduction is characteristic of and all but universal among the higher plants and animals. Sexual reproduction is the product of the union of an egg-cell (a female cell) and a sperm-cell (a male cell). The result of the union is a single cell to which we have already referred as a "fertilized ovum." The egg-cell and the sperm-cell are products of a modification of the mitosis of germ-line cells of the female and the male, respectively. This modification is known as "meiosis." The stages of meiosis will be described later.

Summary of the main facts of the structural and functional heritage that determines the life and health of the protoplasmic cell.

I. *Structural heritage* (*summary*). Every "new" cell begins its life as a microscopic bit of "old" protoplasm that constituted half or approximately half the protoplasm of its parent cell. The fertilized ovum, with which a sexual multicellular organism (plant, animal, and human) begins its life, is an exception to this rule because every fertilized ovum is composed of two very special protoplasmic cells, an egg-cell and a sperm-cell that united to form the fertilized ovum. Thus the structural heritage of the fertilized ovum is composed of all the living protoplasm furnished by each of its parent cells.

The main parts of the living structural heritage of a typical cell may be summarized for our purposes as:

1. The cell membrane—the surface of the cell protoplasm.

2. The cytoplasm—the body of the cell, a reticular (or network) structure with a semifluid content composed of specialized regions, organs, foods, and cell products.

3. The astral bodies—special organs in the cytoplasm and associated with and sometimes a part of the nucleus, essential to reproduction, growth, and transmission of heredity.

4. The nuclear membrane—the surface of the nucleus, a living part of the nucleus.

5. The nucleoplasm—the body of the nucleus, having a reticular structure with a semifluid content composed of specialized organs and regions essential to the functions of the nucleus and of the cell as a whole.

6. The chromatin granules or reticulum—organs of the nucleus that in certain stages of cell activity appear as chromatin threads (the spireme) or chromosomes. They take an essential part in the functions of the cell. The chromosomes contain specialized organs or areas, notably the genes (the factors that determine heredity), that will be discussed in a later chapter.

II. *Functional heritage* (*summary*). The structural and the functional heritage of the protoplasmic cell are inseparable. The fact that they may be separately described must not be misinterpreted. Function depends on structure. The functional heritage described above, upon which the life and health of all protoplasmic cells depend, may be summarized as the functions of:

1. Absorption of chemicals in solution.

2. Assimilation of chemical compounds in solution.

3. Manufacture, repair, and replacement of living structural protoplasm, synthetic chemical reactions.

4. Manufacture of special cell products—the secretions of the cell. Products of synthetic cell chemistry.

5. The storage of special cell products.

6. The transformation of potential energy into kinetic energy, e.g., the production of heat, and the performance of work. Chemical dissociation.

7. The formation of excretions.

8. The elimination of secretions and excretions.

9. Mitosis and meiosis. Functions concerned with growth and reproduction, the transmission of heredity, and the development and specialization of structure and function.

Environmental factors essential to the life and health of the protoplasmic cell.—On the preceding pages we discussed favorable heritage as an essential to the health and life of the cell. We are now concerned with the importance of favorable environmental factors.

Patient, scientific research has proved that the life and health of the protoplasmic cell are dependent on certain essential factors that constitute favorable environment. This principle governs the life and health of every living thing. Among the known factors essential to this environmental favor are:

1. Sunlight. Directly and indirectly the light from the sun is requisite to the life and health of plant and animal cells.

2. Favorable temperature. The life and health of every protoplasmic cell depends upon an optimal range of temperature, above and below which damage or death is inevitable.

3. Available water. Some degree of fluid is essential to every sort of protoplasmic cell. The typical cell is 70 per cent water. Absence of available water in the environment of the cell destroys it. The tissue cells of human beings are bathed with blood serum and lymph. They can live only in a fluid medium. A man weighing 150 pounds is more than 100 pounds of water. Plants, animals, and humans are unable to maintain life in the absence of adequate available environmental water.

4. Environmental free oxygen. Free oxygen is essential to the activities of the protoplasmic cells that constitute the tissues of the higher plants, animals, and man, and to most of the one-celled plants and animals. Free oxygen is mixed with other gases in atmospheric air, including the air present in the interstices of surface soil. It is also dissolved in water, being present in greater degree in fresh water than in the salt water of the ocean. Free oxygen is thus available in water to plants and animals that live in water, in the air and soil to land plants, and in the air to land animals and men.

5. Food supply, an essential factor in the environment of the protoplasmic cell. Every protoplasmic cell, whether it be the single cell of a one-celled organism, or one of the many cells of a multicellular plant or animal, or one of the four thousand billion cells of a mature human being, can live and maintain its health only in an environment in which there is an available food supply containing all the chemicals essential to its life and maintenance. The

special food chemicals essential to the life of one sort of protoplasmic cell may differ from those required by another, but it is safe to state that, in order to be favorable to the life and health of a protoplasmic cell, an environment must furnish sources of appropriate protein foods, carbohydrate foods, fatty foods, vitamins, and inorganic salts.

6. Social environment essential to the life and health of the protoplasmic cell. Every protoplasmic cell that is formed by the union of an egg-cell and a sperm-cell, whether it continues its life as a one-celled organism or is multiplied by mitosis into a many-celled organism, is dependent on a social environment for its heritage of life and for its opportunity to transmit life and heredity to its offspring. The minimum social essential of the protoplasmic cell is that of the sexual one-celled organism for which there must be two parent organisms. The protoplasmic cells of multicellular organisms are increasingly dependent for life and health on a social environment constituted by the various cells that form the special tissues and organs of the multicellular organism of which they are a part. A multicellular plant or animal may be regarded as an immense, organized social community of protoplasmic cells, having a population of many millions, even trillions, of cells, all engaged co-operatively under normal conditions in furnishing a favorable environment for every member (every protoplasmic cell) of the community.

Favorable experience with favorable environment essential to the life and health of the protoplasmic cell.—The maintenance of the life and health of the protoplasmic cell and the possibility of its transmitting a favorable heredity to its offspring depend not only upon its favorable heritage and its favorable environment but also upon favorable interactions between its heritage and its environment—that is to say, it depends also upon the favorable living experiences of the cell with its environment. Favorable heritage, environment, and experience are inseparably requisite to the health and life of the protoplasmic cell, and therefore to the health and life of living things.

Every organ of the cell must be used if it is to grow, develop, and serve its purpose. This fact is in accord with the "biological law of use," or, as it is sometimes worded, "the law of exercise." This "law" is based on an array of facts that prove that functional activity (use, exercise) is essential to the maintenance of the

health and life and the development of the organ or organism, while inactivity (disuse) prevents development and leads to atrophy or death.

The activities of the living cell are responses to directive "hungers" from within the cell and to the stimulating influences of environmental factors. These activities are dependent upon the availability in the environment of conditions and factors that the cell must utilize for the maintenance of its life. Thus the protoplasmic cell must secure by the drive of its own heritage of functional activity, or have brought to it by the aid of physical influences outside itself or by other living cells or organisms, the sunshine and temperature it must have, and the water, free oxygen, food chemicals, inorganic salts, and vitamins which it may absorb and assimilate and with which it may build its living protoplasmic structure, manufacture its secretions, synthesize potential energy, transform potential energy into kinetic energy, produce heat, and perform work.

Any influence that favors these interactions—these experiences—is a favorable health influence. Any influence that obstructs them is an unfavorable health influence.

The fundamental behaviors of all living things—one-celled organisms, multicellular plants, animals, and human beings—are forced behaviors (autonomic behaviors) determined by the requirements of the protoplasmic cell for sunshine, favorable temperature, adequate supply of free oxygen, water, food, inorganic salts, and vitamins; for reproduction and transmission of heredity; and for protection in the exercise of the functions that enable them to make use of these availabilities and thus satisfy the requirements of the protoplasmic cell for the maintenance of its health and life.

These forced behaviors, these essential functional experiences of the protoplasmic cell with environment, form the basis of the practice of hygiene by multicellular mankind—the practice of hygiene by the individual, by the family group, by other groups, and by society.

Every living cell is a product of the reproductive experience of the cell or cells from which it received its gift of life and its heritage of structure and function. Every living cell maintains its health and life through favorable experience with environment. These essential experiences are interactions between cell and en-

vironment. The experiences of securing these requisites from environment vary with the organisms and environment involved. A protoplasmic cell living as a one-celled organism in a pool of stagnant water, or as one of a multitude of protoplasmic cells living together as a redwood tree in a primeval forest, or existing as a single member of a tissue-cell community of four trillion protoplasmic cells co-ordinating, co-operating, integrating, and serving as a single human being living as a citizen in his own home town, is subject to the same environmental essentials for health and life; but the nature of the experiences or interactions of the protoplasmic cell necessary for securing those essentials obviously differs in the stagnant pool, the forest, and the home town. The one-celled plant or animal in a stagnant pool interacts directly with its water environment upon which its "favorable experience" depends. The organism that has no power of motion holds its fixed position and depends on environmental movements for the transportation to it of the chemical supplies it must absorb in order to live.

The many-celled redwood tree maintains health and life, grows, reproduces itself, and transmits its heredity as long as its experiences with its environment give it sunshine and an optimal temperature range and enable its living protoplasmic cells to interact adequately with the gases from the air and the chemical solutions from the soil that contain the chemical molecules essential to its existence. The redwood tree and all other multicellular plants, having no power of motion enabling them to search from place to place for the satisfaction of their requirements for the maintenance of life and health, can live only in environments in which these essentials are brought to them.

The many-celled animal with the power of locomotion on land, under water, or in the air spends its active life mainly if not wholly in search for environmental situations that supply its requirements. The protoplasmic cells of the many-celled animal are commonly known as tissue cells. The tissue cells of the animal are, in the main, fixed cells. Certain tissue cells float in the blood stream. Certain other tissue cells have the power of motion enabling them to move from place to place between other tissue cells of the animal. Hence it is safe to state that the tissue cells (the protoplasmic cells) of the many-celled animal are fixed or stationary cells and utterly dependent upon influences outside them-

selves as individual cells for favorable environment. The life of the many-celled animal as a whole is therefore largely if not wholly a life of forced behaviors concerned with satisfying the requirements of its constituent tissue cells for the tissue-cell environment (the blood and lymph streams mainly) having an optimal temperature range, and containing free oxygen, water, food, vitamins, and inorganic salts, and furnishing safety.

The behaviors of the human being are for the same reasons determined basically by the requirements of the human tissue cell —the human protoplasmic cell. Human behaviors are fundamentally forced behaviors. They are forced because life and health must be produced, maintained, and defended despite the helplessness of the fetus and the infant, the ignorance and helplessness of the child, and the ignorance, misinformation, and dependence of youth and maturity. Our behaviors are fundamentally forced behaviors (autonomic behaviors) because there are no other ways for the individual to provide a fluid internal environment containing an adequate supply of free oxygen (respiratory oxygen), of foodstuffs (proteins, carbohydrates, and fats), of vitamins, and of inorganic salts essential to the health and life of his tissue cells even as they are to the health of every other protoplasmic plant or animal cell.

Levels of mind in relation to favorable experience with favorable environment.—The intelligent, reflective mind of the human being provides a voluntaristic government of human behavior that, through the long ages of human experience, has slowly built a culture of enlightenment that obscures the underlying autonomic (forced) nature of human behavior. We have noted that every one of our ancestors arrived in the world as a bit of human living protoplasm furnished jointly by two parents and endowed with a heritage of health. There is no other way. Every one of us lived, grew, and developed through infancy, childhood, and youth in consequence of the favorable prenatal and postnatal experiences of that bit of living protoplasm and its descendants. These experiences were the internal environmental experiences of our tissue cells, tissues, and organs, and the external environmental experiences of our bodies, each body behaving as a whole organism. As a fertilized ovum and as an unborn infant, our requirements of internal environment were satisfied by the temperature, oxygen, water, proteins, fats, carbohydrates, inorganic

salts, vitamins, and safety furnished by the maternal womb—the external environment of the embryo and fetus. These experiences of the protoplasmic cells (the tissue cells, tissues, and organs) of the prenatal infant with the internal and external environments of the infant are autonomic, forced experiences. There is no voluntaristic activity involved so far as the unborn infant is concerned. The mind that governs the behaviors of the embryo and fetus is an autonomic (i.e., a self-regulating) mind, a mind of physical chemical reactions, hormones, tropisms, and reflexes. This sort of mind governs the interactions between the living protoplasmic cells of the unborn child and the internal environment. It is the same sort of mind that governs the experience of the unborn child with its external environment—the environment furnished it by the maternal womb.

But from the moment of birth, the normal human infant exhibits evidence of a government of its behaviors by higher levels of mind, one of which we may describe as instinct mind, and another and higher level as intelligent, reflective mind. These higher levels of mind may be described as levels of voluntaristic mind. Government by voluntaristic mind enables the infant to exhibit purposeful behaviors that, along with its autonomic behaviors, are drives or urges that are concerned with the satisfaction of its inescapable needs.

But the infant mind is a helpless mind and depends entirely upon aid from its human social environment for assistance in the satisfaction of its native urges for the requirements that must be met if it is to maintain health; grow; become physically, mentally, and socially educated; escape postponable death; and make its contribution to the welfare of society. Thus there is a compelling dependence of every one of us upon the external environment furnished by his home group and other groups, and by his community, for his arrival in the world and for his maintenance, protection, and education after that arrival. And all these favorable external environments are favorable to the individual only in the event of a favorable interaction (experience) between the protoplasmic cells of the individual and his internal environment that he furnishes for them.

Inseparability of heritage, environment, and interaction between heritage and environment of the protoplasmic cell.— We have described very briefly certain facts concerning the essen-

tial requirements of favorable heritage, favorable environment, and favorable interaction (experience) between heritage and environment that give origin to the principles and practices of human hygiene. It is obvious that the life and health of the protoplasmic cell and therefore of every human being are utterly dependent on the satisfaction of all three of these requirements. There can be no living cell in the absence of favorable environment, nor can there exist a living organism—plant, animal, or human—in the absence of favorable environment. We study and discuss organisms, environment, and activity separately, but the inescapable fact remains true that health and life are utterly dependent on all three.

Summary.—The facts presented in this chapter prove that the principles and practices that ultimately determine and regulate the production, maintenance, improvement, and defense of human health and life are based on the principles and practices that construct and defend the health and life of the protoplasmic cell. They are fundamentally the principles and practices that determine the health and life of every living thing. The human being, like every other living thing, must begin life as a single protoplasmic cell, endowed with a favorable heritage, and competent to transmit a favorable heredity; must begin and live life in a favorable environment; and must interact favorably with environment.

Because of their origins in the biology of the protoplasmic cell, the principles and practices of human hygiene may be considered in four groups. For this reason, this text, *Principles of Hygiene,* and its companion text, *The Practice of Hygiene,* will discuss these four groups as follows:

Group I. The principles that determine and regulate the constructive and defensive hygiene of heredity and reproduction: (1) the transmission of germ-line heredities that produce the mature ovum or sperm (mitosis and meiosis); (2) the reception of parental heritages on fertilization of the ovum by the sperm; and (3) the growth and development of the fertilized ovum (mitosis) into a child (i.e., reproduction).

Group II. The principles that determine the constructive and defensive hygiene of heritage: the structural and functional requirements of the somatic-line cells whose satisfaction determines and regulates somatic, mental, and social growth and development.

Group III. The principles that determine and regulate the

hygiene of environment: (1) physical environment, favorable as to temperatures, sunlight, free oxygen, water, inorganic salts; (2) biological environment, favorable as to available plant foods and food plants and animal foods and food animals; (3) social environment, favorable as to mating, family life, group life, and social organization.

Group IV. The practices of hygiene. The practices (behaviors) of individuals, families, and other groups, and of society that are forced or persuaded in order that the interactions necessary to produce, improve, maintain, protect, and defend the life and health of the protoplasmic cell may take place between the cell and its environment (the internal environment of the individual of whom the cell is a part). The principles that determine these practices are described here as principles of somatic health, mental health, and social health. They determine the practices (the autonomic and voluntaristic behaviors) of individual hygiene, group hygiene, and societal hygiene.

CHAPTER IV

PRINCIPLES OF HEREDITY THAT DETERMINE PRINCIPLES OF HYGIENE

Preview of chapter.—This chapter has to do with principles of heredity that, under the influence of favorable experience with favorable environment, determine and regulate heritage of dynamic and potential life and health. It will call attention to the main sources of our information concerning the principles of heredity, referring to empirical origins and covering in some detail the fundamental contributions of plant hybridization and of cytology.

Definitions of heredity.—The difficulty of defining heredity is due to the fact that heredity is a cause, a process, and an effect. It is concerned with the factors that determine in offspring the presence and absence of physical, mental, and social characters and qualities that resemble their parents. It is concerned with the transmissibility and transmission of these factors from parents to offspring. It is concerned with the formation of heritage received by the offspring. This heritage with which the life of every human being begins is in that beginning a single protoplasmic cell, a fertilized ovum made of two cells—one transmitted from the mother and the other from the father. This single-cell heritage is a whole individual. It is a living, dynamic organism utterly dependent on the favor of its experience with environment. This living fertilized ovum is first a heritage potential with the possibilities of the growth and development of somatic-line cells into physical, mental, and social maturity. It is, second, a heritage potential with the possibilities of growth and development of germ-line cells into transmissible mature sperms or ova that, uniting in fertilization with mature germ-cells of a mate, transmit a joint parental heredity to the fertilized ova thus produced.

The difficulty of defining heredity is evident in the following quotations from various authorities: (1) "The influence of parents upon offspring, transmission of qualities or characteristics, mental or physical, from parents to offspring";[1] (2) "Heredity may be defined as the resemblance between an organism and its ancestors insofar as this resemblance is not due to similarity of

[1] *Century Dictionary.*

environment";[1] (3) ". . . . a word having many definitions, but best scientifically defined as the internal control of development";[2] (4) "Heredity is the process which is responsible for the particular combination of transmissible characters possessed by any organism . . . . the definition makes heredity responsible for the differences between parents and offspring as well as their resemblances."[3]

We are interested in heredity here because heredity is the process that transmits living causes that, under the influence of favorable experience with favorable intra- and extra-cellular environments, determine the production, improvement, maintenance, and defense of the health and life of the individual they develop and the transmissible causes of heredity of which they make his germ-line cells custodian.

We have defined hygiene as principles and practices that determine and regulate the production, maintenance, improvement, and defense of life and health. We know that the process of heredity transmits dynamic factors that constitute the living heritage of the fertilized ovum and that this dynamic heritage interacts as a whole with the environment of the fertilized ovum, constructing, improving, or defending its health and life. If the heritage is a favorable health heritage, if the environment is a favorable environment, then the interactions between heritage and environment produce, maintain, improve, and defend the health and life of the fertilized ovum and its living, interdependent progeny that constitute the individual. Thus, the principles of heredity are principles of hygiene that determine and regulate health through maintenance, growth, and development of the individual.

On the other hand, heredity may furnish factors that make favorable experience with environment difficult or impossible and therefore injure health, destroy life, or even prevent life, regardless of the favor of environment. Thus, heredity may be a source of health injury and of disease.

Source of our knowledge of the principles of heredity.—Our knowledge of the principles of heredity has been secured through (1) empirical observation, (2) statistical study, (3) plant and animal experimentation, and (4) cytological investigations,

[1] *Encyclopaedia Britannica*, Fourteenth Edition.

[2] C. B. Davenport, *National Encyclopedia* (1933).

[3] Burlingame, Heath, Martin, Peirce, *General Biology* (1928), p. 340.

that is to say, through investigation of the behaviors of the living protoplasmic tissue cell under observed and controlled conditions. *Empirical* observation recognized the existence of principles of heredity a very long time ago. Plutarch, describing the social program of Lycurgus, who lived at some uncertain time in the period covered from the tenth to the seventh centuries, B.C., inclusive, gave evidence of a knowledge of the principles of heredity among the Spartans of his time. According to Plutarch, Lycurgus insisted that children should be born of the best men and women; that children of "a bad breed" would prove their bad qualities; and that "well-born" children would prove their good qualities. Plutarch is authority for the statement that Lycurgus called attention to the fact that the cultures of other nations of his time were concerned with breeding fine dogs and fine horses but paid no attention to the breeding of fine children.[1] Plato (427 to 347 B.C.) in his *Republic* advanced the same ideas concerning the desirability of producing superior children in his ideal state. Plato's plan proposed the mating of superior parents, the segregation of superior children and their education by the state, the prevention of reproduction by inferior mates, and the destruction of inferior progeny. There is evidence here of an empirical knowledge of the working of the principles of heredity that preceded by at least three thousand years our present-day scientific knowledge of these principles.

The Egyptians recorded their belief in the principles of heredity in their long-continued custom of marriage between the Pharaoh and one of his sisters in order to produce children of pure royal descent to succeed him as Pharaoh.

Other ancient people, notably the Peruvians, have exhibited their beliefs in the principles of heredity to the extent of marriage between their king and his sister in order to maintain untainted the royal line of descent.

A belief in the principles of heredity accounts in part at least for the long-standing customs and even the laws of some nations that provide for marriage between royal families and prohibit the royal succession of children born of marriage with one not of royal blood.

The caste system of India is a social pattern based on a belief

[1] See W. E. Castle, *Genetics and Eugenics* (Harvard University Press, 1930), pp. 388 ff.

in the operation of the principles of heredity that originated many centuries ago in empiricism.

Conclusion: It may then be safely stated that empirical observation furnished the belief among people in various parts of the world several thousand years ago that physical qualities of health or lack of such qualities are transmissible from parents to children and that the folkways, mores, laws, and institutions of these peoples were profoundly influenced by this principle of heredity and hygiene.

The *statistical studies* of Francis Galton (1822–1911)[1] are the best of our present sources of information concerning the principles of heredity that have been contributed by statistical investigations. Francis Galton began publishing his conclusions in 1865. These conclusions were based on a statistical study of averages. His method was to gather exhaustive details concerning the histories of all the members of all the families of all the men and women of superior achievement along certain related lines, to classify all the family members on the basis of their relative gradations as to achievement, and then to compare these classifications within each group. His evidence was concerned with the following fields of achievement:

1. Judges	7. Poets
2. Statesmen	8. Musicians
3. Peerage	9. Painters
4. Commanders	10. Divines
5. Literary men	11. Oarsmen
6. Men of science	12. Wrestlers

The statistical studies that preceded Galton were concerned with the inheritance of physical traits. Francis Galton produced convincing evidence that mental traits and capacities are heritable. He proved statistically the heritability of superiority and of inferiority. The impressiveness of his findings stimulated him to found the Eugenics Movement that has been concerned with race betterment ever since his time.

The first published results of Galton's work in the field of heredity appeared in 1865. Others of his publications followed. Two of his generalizations are now known as "Galton's Laws of

[1] Francis Galton, *Hereditary Genius* (Macmillan, 1914).

Heredity." The first of these is to the effect that the hereditary influence of a generation of ancestors is reduced by one-half with each subsequent generation. This is Galton's "General Law of Ancestral Inheritance." It was his belief that the two parents contribute between them, on the average, one-half the heredity of their offspring; the four grandparents, one-fourth; the eight great-grandparents, one-eighth; and so on, the total ancestral line contributing thus, by diminishing fractions, the total heritage of the individual. The second conclusion of Galton is now known as the "Law of Regression." It is to the effect that children tend to differ from their parents, the difference being toward the general average of the race. The children of parents with exceptional characteristics, according to Galton, show those qualities to a less degree than their parents.

Neither of Galton's laws is useful for purposes of precision. His Law of Ancestral Inheritance does not enable one to predict the transmission of a specific heritable character. But his work supplies impressive evidence that exceptional mental capacities are inherited. He was the first outstanding scholar to call serious attention to the biological inheritance of human mental traits and capacity.[1] Most of his predecessors were concerned with the inheritance of physical characteristics. Galton's Law of Regression has been disproved by more recent researches in which germinally pure lines have been observed. Experiments with plants and records of human experience show that regression does not occur in characters carried in germinally pure lines.

Conclusion: Statistical studies of heredity have proved that mental as well as physical traits are transmitted through heredity from parents to children. These studies, particularly those of Francis Galton, are responsible for the Eugenics Movement that is concerned with the use of this principle of heredity for the production, improvement, and defense of the heritable mental and physical health of mankind, and for the eradication of heritable mental and physical defect, deficiency, and disease.

Experimental plant hybridization as a source of knowledge of the principles of heredity.—C. B. Davenport defines hybridism as "the theory and practice of sexual crossing of in-

[1] Vernon Kellogg, *Mind and Heredity* (Princeton University Press, 1923), p. 43.

dividuals (strictly, the union of their germ-cells) belonging to dissimilar species, varieties, races, or strains."

Joseph Gottlieb Kölreuter (1733–1806).—The first systematic experimental research in the field of plant hybridization was done by Kölreuter, a German botanist, between 1760 and 1766.[1] This investigation proved "for the first time the fact that the seeds of plants are produced by a sexual process comparable with that known to occur in animals." His work ". . . . also led to a knowledge of the general behaviors of hybrid plants which was scarcely bettered until Mendel made his observations a century later."[2] He "established the occurrence of sexual reproduction in plants showing that hybrid offspring inherit equally from the pollen plant and the seed plant." C. Naudin (1815–1899), a Frenchman, assembled in 1861 the then known facts of hybridization in plants. His summary of the experimental work of Kölreuter and other investigators, including his own (on such plants as flax, thorn apple, four-o'clock, and petunia), enabled him to announce some important conclusions that anticipated the now classic "Laws of Mendel." Thus a number of experimenters with plant breedings furnished the basis for the remarkable added service of Mendel.

Gregor Johann Mendel (1822–1884).—The methods of this student of plant hybridization led to some of the most important of the fundamental contributions that have been made to our knowledge of the processes of heredity. A somewhat detailed consideration of his methods and results is justified because of their basic significance to our understanding of the principles of heredity and therefore to the principles of hygiene furnished by heredity. Gregor Mendel was appointed as a "supply teacher" in the Brünn Modern School, Brünn, Moravia, in 1854. He taught physics and natural history. His experimental hybridization program was carried on in a small garden of the "stately Augustinian monastery of Altbrünn," a garden "only one hundred and twenty feet long and a little over twenty feet wide, but small though it is, it has become of historical significance."[3]

[1] The facts in this discussion are drawn from W. E. Castle, *Genetics and Eugenics*, chap. xiii.

[2] Quoted from Lock, by Castle, *op. cit.*, p. 128.

[3] Hugo Iltis, *Life of Mendel*, translated by Eden and Cedar Paul (George Allen & Unwin, 1932), p. 107.

Iltis writes:

> During the fifties and sixties of the nineteenth century, anyone passing this way might have seen, on fine spring days, a vigorous, short, rather sturdily built and somewhat corpulent man engaged in a laborious occupation which would have been puzzling to any uninstructed observer. Here there were to be seen, clinging to staves, the branches of trees, and stretched strings, hundreds of pea plants of the most various kinds, with white and with violet blossoms, both tall and dwarf, some destined to bear smooth and others wrinkled peas. The gardener would move from one flower to another, opening with fine forceps the blossoms that had not opened spontaneously, removing the keel and carefully detaching the anthers, then with a camel's hair pencil, he would dust the pollen upon the stigma of another plant and would subsequently enwrap the flower thus treated in a little bag of paper or calico, to prevent any industrious bee or enterprising pea weevil from transferring pollen from some other flower to the stigma thus treated and in this way invalidating the result of the hybridization experiment. The investigator's patience was indefatigable.[1]

In his report on these investigations before the Brünn Society for the Study of Natural Science in 1865, after eight years of experimental hybridization, Mendel made the following statement stressing the three conditions of experimental procedure that he regarded as essential to successful experimental hybridization.

> Those who survey the work done in this department will arrive at the conviction that among all the numerous experiments made, not one has been carried to such an extent and in such a way as to make it possible to determine the number of different forms under which the offspring of hybrids appear, or to arrange these forms with certainty according to their separate generations, or definitely to ascertain their statistical relations.[2]

Bateson remarks that "it is to this clear conception of these three primary necessities that the whole success of Mendel's work is due. So far as I know the conception was absolutely new in his day."[3]

In order to satisfy these experimental conditions, Mendel followed three lines of procedure that, according to Iltis, differed from any preceding procedures in experimental plant hybridization:

> Whereas his predecessors had hybridized species or varieties which differed from one another more or less in very numerous qualities, he hybridized forms of the same species which differed from one another only in respect of one or a few characters . . . . second . . . . was not content to examine the outward aspect of the hybrids and their offspring but paid

[1] Iltis, *op. cit.,* p. 107.

[2] W. Bateson, *Mendel's Principles of Heredity* (Cambridge University Press, 1913), Appendix, p. 336. [3] *Ibid.*

especial attention to the numerical ratios in which hybrids exhibiting various characters appeared. He [Mendel] writes: "In order to ascertain the relationships in which the hybrid forms stand to one another and to their progenitors, it would seem to be necessary that we should observe the total number of the members of the developmental series in each successive generation . . . . the true numerical ratios can only be deduced from the greatest possible number of individual values; and the greater the number of these the more effectively will mere chance be eliminated." The third great advance marked by the method of Mendel's experiment was this that he took a separate view of each plant obtained during a hybridization experiment, collecting and sowing the seeds of each individual separately (individual culture). In like manner he kept the separate generations of the hybrids carefully apart, whereas his predecessors with few exceptions had contemplated the whole of the offspring as one great chaos.[1]

Mendel reported his researches in 1865. They were published in 1866 in the *Proceedings of the Brünn Society for the Study of Natural Science.* His work was unnoticed until its discovery by Hugo De Vries in 1899. De Vries published his researches in hybridization in 1900. In April of the same year Karl Correns published a paper on "Gregor Mendel's Rules concerning the Behavior of Racial Hybrids." Two months later the Viennese botanist, Erich Tschermak, wrote a paper in which he also announced the discoveries of Mendel. These three students of plant hybridization, ignorant of Mendel's researches, working independently, rediscovered the fundamental principles of heredity thirty-four years after their announcement by Mendel at Brünn in 1865. Within a few years after the verifications of De Vries, Correns, and Tschermak, the research activities of many other competent students in the fields of plant hybridization and of animal hybridization had assembled a scientific knowledge of the Mendelian principles that proves their validity for plants, animals, and human beings.

It is obvious from the foregoing record that the study of heredity is under a debt to De Vries that is quite as great as its debt to Mendel. It would be unfair, too, to omit the suggestion that there is also a debt to Correns and to Tschermak. But the fact remains that Mendel's research procedure is an outstanding standard of simplicity, clarity, and scientific method that has determined the scientific method and influenced scientific thought in this field ever since the reports thereon by De Vries, Correns, and Tschermak in 1900.

[1] Iltis, *op. cit.,* pp. 130–31.

Gregor Mendel's experiments in plant hybridization.—It was noted above that Mendel insisted that it was necessary (1) that experimental hybridization should be carried on "to such an extent and in such a way as to make it possible to determine the number of different forms under which the offspring of hybrids appear," (2) "to arrange these forms with certainty according to their separate generations," and (3) "definitely to ascertain their statistical relations."

It was noted above further, in a quotation from Iltis, that Mendel's experimental procedures differed from those of his predecessors in three very important details: (1) they hybridized species or varieties that differed from one another more or less in very numerous qualities, while he hybridized forms of the same species which differed from one another only in respect to one or a very few characters; (2) he was not content, as they were, to examine only the outward aspect of hybrids, and their offspring, but maintained a numerical classifying inventory that included every member of every series in each successive generation; and (3) "he took a separate view of each plant obtained during a hybridization experiment, collecting and sowing the seeds of each individual [plant] separately . . . . he kept separate generations . . . . apart, whereas his predecessors with few exceptions had contemplated the whole of the offspring as one great chaos." A statement of Bateson summarizes these postulates as follows:

> In order to obtain a clear result he saw that it was absolutely necessary to start with pure-breeding homogeneous materials, to consider each character separately, and on no account to confuse the different generations together. Lastly, he realized that the progeny from distinct individuals must be separately recorded. All these ideas were new in his day.[1]

Mendel's selection of contrasting pure-line characters for experimental hybridization.—After two years spent in the selection and testing of varieties of pea plants (*Pisum sativum*) under the controlled conditions stated above, he chose fourteen varieties of plants out of the thirty-four varieties that he had under observation. He chose these fourteen varieties because they remained constant in certain of the characters they showed, generation after generation. Characters that appear without change, generation after generation, under such experimental conditions are known as products of "pure-line heredity." The fourteen varieties of

[1] W. Bateson, *op. cit.*, p. 7.

plants exhibiting pure-line heredities chosen by Mendel were selected because they furnished seven pairs of sharply contrasting characters that may briefly be described as follows:[1]

1. Tall plants (5 to 6 feet tall) and short plants (9 to 18 inches tall).

2. Plants producing flowers distributed along the axis of the plant and plants producing flowers bunched at the top.

3. Plants all of whose unripe pods are colored a shade of green and plants whose unripe pods are all bright yellow.

4. Plants whose pods are all simply inflated and plants whose pods are all deeply constricted between the seeds.

5. Plants whose seed skins are all of various shades of gray or brown with or without white spotting, or plants all of whose seed skins are white.

6. Plants all of whose cotyledons are yellow and plants all of whose cotyledons are green.

7. Plants whose seeds are all rounded and plants whose seeds are all wrinkled.

Mendelian dominant and recessive characters.—Gregor Mendel's experimental hybridization of pea plants was carried out during a period of eight years. We have noted that he cultivated each plant separately as an individual plant. He controlled the fertilization of selected plant ova by selected plant sperms by opening the plant bud before it was perfectly developed, removing the keel, extracting each stamen with a forceps, then dusting the stigma with the foreign pollen, thus controlling the fertilization of the ova by the sperms, and finally enclosing the plant bud in a protecting paper or calico bag. He collected the seeds (the embryos) of each plant and saved them separately. He recorded the classified results of 19,959 carefully observed, scientifically controlled experimental hybridizations.

His observations show that the crossing (union of germ-cells in fertilization) of plants that have pure-line heredities for the same character produces seeds that grow into plants that exhibit the same pure-line character. Thus, the fertilization of the ova of pure-line tall pea plants always produces pure-line tall pea plants. The fertilization of the ova of short pea plants by sperms of short pea plants always produces short pea plants.

Mendel found that on crossing a pure-line character with a

[1] These descriptions are patterned after those of Bateson, *op. cit.*, p. 14.

pure-line contrasting character one of the two contrasting characters was not evident in the offspring. Thus the children produced by tall pea plants mated (crossed) with short pea plants were all tall children. Not one of them showed the character of shortness. But when he crossed the offspring of the children of plant parents exhibiting contrasting characters with each other, a few of their plant children showed the character that had disappeared in their parents. Thus, a crossing of tall plants, one of whose parents was tall and the other short, with tall plants of the same sort of tall-short parentage produced always a few short plants. The mathematical regularity with which certain characters disappeared and reappeared under the experimental conditions set up by Mendel led him to the conception of "dominant" characters and "recessive" characters. He proved that in *Pisum sativum* tallness is a dominant character and shortness a recessive character; axial distribution of flowers dominant and terminal distribution recessive; unripe green color of pods dominant and bright yellow recessive; inflated pods dominant and deeply constricted pods recessive; seed skins of various shades of gray or brown dominant and skins all white recessive; yellow color of cotyledons dominant and green color recessive; round form of seed dominant and wrinkled seeds recessive.

Gregor Mendel's conception of dominant characters and recessive characters has been tested in all parts of our scientific world by an enormous number of scientifically controlled observations on plants and animals. His conception is now universally accepted as a fact.

Unit-like behavior of the factors that determine pure-line characters.—Crossing of a pure-line dominant with a pure-line recessive produces offspring showing the dominant character. These offspring are hybrids so far as the character under consideration is concerned. Thus the crossing of plants of a pure-line heritage for tallness with plants of a pure-line heritage for shortness produces tall plants that are hybrids for tall-shortness. The crossing of hybrid tall plants with hybrid tall plants produces some plants that are tall and a few that are short. The ratio is three tall to one short (see Fig. 8). The behaviors of these heritable characters are the behaviors of unit-like factors that determine the character. The reappearance of recessive characters in the offspring of hybrids whose parents gave no evidence of the

recessives is an evidence of a unit-like behavior of the factors that determined the recessives.

The Mendelian characters behave like units in their appearance and disappearance in successive generations. We shall discuss the nature of these units on later pages.

The Mendelian ratios.—The experimental hybridizations of Gregor Mendel proved that contrasting dominant and recessive characters appear in fixed mathematical ratios in successive hybrid generations. The ova and sperms of plants or animals of the same pure-line heritage, on fertilization, produce plants or animals all of which show the same pure-line character.

Ova or sperms from a plant or animal showing a dominant character united in fertilization with sperms or ova of a plant or animal showing the contrasting pure-line recessive of that character produce offspring all of which are hybrids showing the dominant character.

Ova or sperms from a plant or animal that is hybrid for a given pair of contrasting characters united in fertilization with sperms or ova of a plant or animal that is hybrid for the same contrasting characters produce offspring that show the contrasting characters in the ratio of three with the dominant character to one with the recessive character. This is the three-to-one Mendelian ratio (see Fig. 8).

Matings between these offspring that show the dominant character produce a second generation in which the offspring show characters in the same ratio, three dominant to one recessive.

But an individual cultivation of these offspring showing the dominant character proves that they carry these contrasting characters in the Mendelian ratio of one pure-line dominant to two hybrid dominant-recessive to one pure-line recessive.

We have been considering the Mendelian ratios that are produced when hybrids of a single pair of contrasting characters are crossed. We have thus noted that when the ova and pollen of tall-short hybrid plants are brought together the seeds produced grow into plants in a ratio of three tall plants to one short plant. Our observations have shown that this ratio is made up of a ratio of one plant of pure-line dominant heritage for tallness to two tall plants of hybrid heritage of tall-shortness, to one plant of pure-line recessive heritage for shortness. The elements in the germ-line cells that determine tallness or shortness (dominant character or reces-

sive character) are segregated within those germ-cells in the process of transmission from parents to offspring so that these elements retain their identity and behave like units. When the germ-line cells of a hybrid of tall-shortness mature into ova or sperms, the elements that determine tallness are present in half the mature germ-cells (ova or sperms) and the elements that determine shortness are present in the other half. Therefore, chance fertilization of ova and sperms from such a hybrid source would produce the numerical ratios of three tall to one short plant, and the tall plants would be in the ratio of one pure tall to two hybrid tall-short. This segregation in the germ-cell of the elements that determine and transmit dominant or recessive characters is known as Mendel's First Law—the law of the segregation of the germ-cell elements that determine hereditary characters. Since the time of Mendel the word "gene" has come into use, replacing the word "element" in this connection. This First Law of Mendel is stated nowadays as the "Law of the Segregation of the Genes." We shall discuss the genes in some detail in a later chapter.

The Mendelian ratios that we have been discussing so far are the ratios of dominants to hybrids to recessives produced when hybrids of a single pair of contrasting characters are inbred. Mendel demonstrated further that the offspring of the crossing of hybrids of two pairs of contrasting characters and the offspring of the crossing of hybrids of three pairs of contrasting characters appear in precise mathematical ratios of pure dominants to hybrid dominant-recessives to pure recessives.

In order to determine the ratios in which dominant and recessive characters would be present in the crossing of hybrids having two pairs of contrasting characters Mendel fertilized the ova of plant parents having seeds of a dominant round form and a dominant cotyledon color of yellow with pollen plant parents having seeds with the contrasting recessive wrinkled form and with cotyledons colored with the contrasting recessive green. More concisely, he crossed peas having yellow round seeds with peas having green wrinkled seeds.

The seeds produced by this crossing of two pairs of dominants with two pairs of contrasting recessives grew into hybrid plants that showed—all of them—the dominant characters of yellow and round seeds.

Inbreeding these hybrid plants produced offspring that showed

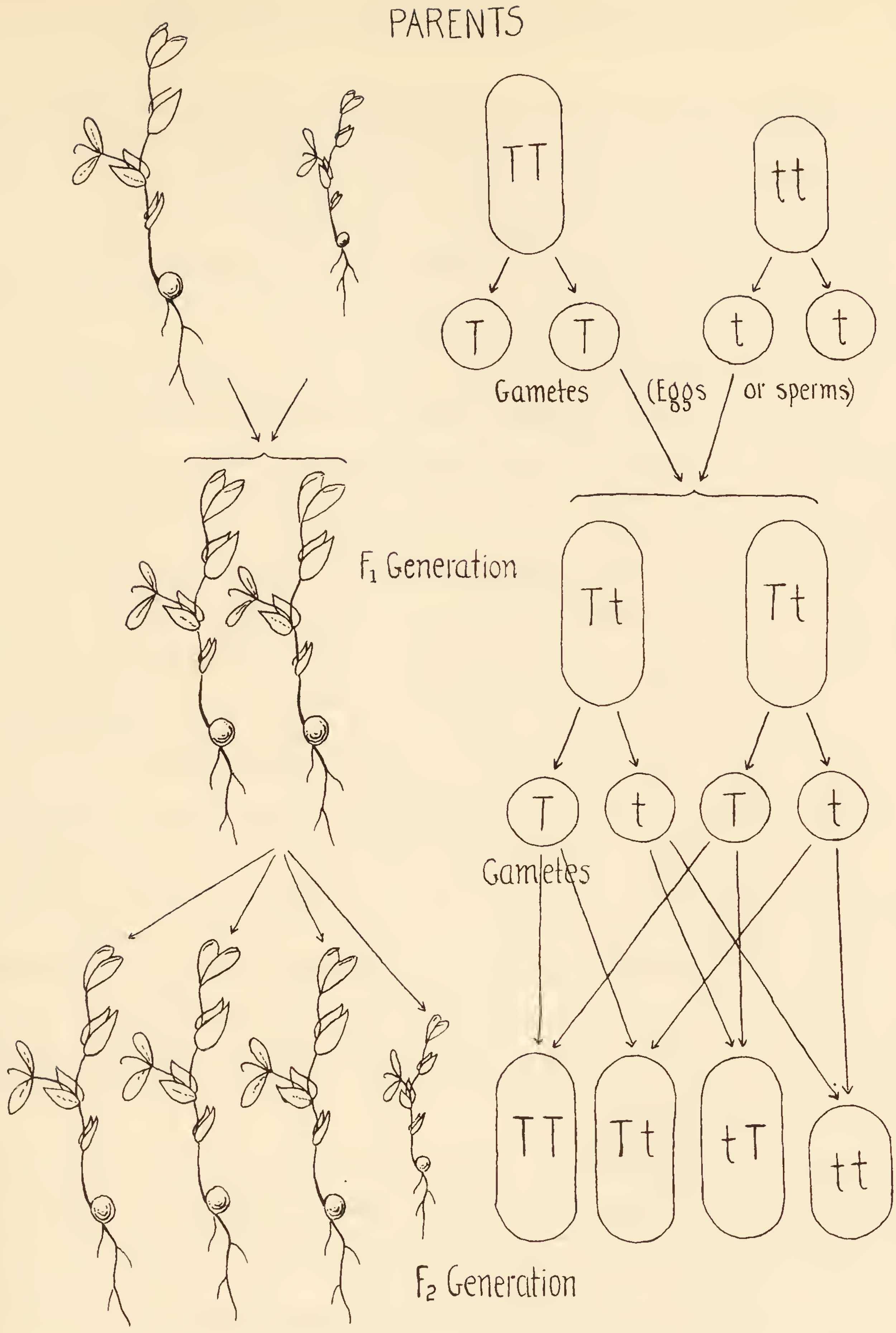


FIG. 8.—Diagram illustrating the crossing of a tall pea plant with a dwarf variety. The result in the F_1 generation is tall plants. If members of the F_1 generation are interbred, the result is three tall plants to one dwarf. On the right, the factors or genes of the tall plant cells are represented by *TT,* and by *tt* in the dwarfs. In the reduction division, or meiosis, every germ-cell of the tall plant contains a *T,* while those of the dwarf hold a *t.* In crossing the fertilized eggs, each contains *Tt, T* being dominant over *t;* the result is a tall plant. When these hybrid F_1 plants develop gametes (i.e., eggs or sperms), each contains either *T* or *t* genes. Interbred, the resulting combination is *TT, Tt, tT, tt.* Since *T* is present in three of these combinations, being dominant, the ratio is three tall to one dwarf.

the dominant round form and the recessive wrinkled form in a ratio of three round to one wrinkled. It produced plants that showed the dominant yellow color of cotyledon and the recessive green in the ratio of three yellow to one green.

Further inbreeding showed that the ratio of one dominant to two dominant-recessive to one recessive was maintained for each of the two pairs of contrasting characters.

An explanation of these facts led to the statement of the so-called Second Law of Mendel, which is to the effect that when two or more pairs of contrasting characters enter into a cross-fertilization the elements in the germ-cells (eggs and sperms) that determine these characters behave independently of each other, so that the offspring produced display dominant and recessive characters in accord with the Mendelian ratios. This Second Law of Mendel is the "Law of the Independent Assortment of the Elements" that determine heritable characters, or, making use of the more recent word "gene" in place of the word "element," we have the "Law of the Independent Assortment of the Genes."

Conclusion.—The plant hybridization experiments of Mendel, De Vries, Tschermak, and their followers, and the animal hybridizations of authorities in that field, have placed experimental research in heredity on a basis of scientifically proved fact. Our knowledge of Mendelian dominants and recessives and of Mendelian ratios has given us principles of heredity that enable us, within limitations, to predict the heritage of physical, mental, or social health or of disease that will be received by the offspring of parents of known heredities.

Blending inheritance.—The seven pairs of contrasting heritable characters chosen by Mendel for his experiments with plant hybridizations revealed a complete dominance of one character over its recessive contrasting character. The hybrid pea-plant children produced by crossing a pure-line dominant character with its pure-line contrasting recessive character (e.g., an ovum of *Pisum* carrying genes for tallness fertilized by a sperm of *Pisum* carrying genes for shortness) produce only tall pea plants. Crossing these hybrid tall-short plants with each other produces tall plants and short plants in the ratio of three tall to one short. This ratio consisted of one pure tall to two hybrid tall-short to one pure short plant. The dominant heredity in such a crossing is definite and complete.

But there are many other crosses of contrasting heritable characteristics that produce hybrid offspring that do not show obvious evidence of dominance. Prior to the discovery of Mendel's report in 1900, observers of hybridization experiences noted that hybrid characters were commonly intermediate between the contrasting characters of their parents. For instance, the mulatto children of a white father and a Negro mother display intermediate color heritages that are neither "pure" white nor "pure" black. Galton classified these as cases of "blending inheritance."

Blending of color in heredity.—The patient researches of De Vries proved that crossing a white-flowered variety of the four-o'clock (*Mirabilis jalopa*) with a red-flowered variety of four-o'clock produces hybrid plant children all of which bear pink flowers. Self-fertilizations of these hybrid pink-flowering plants produce white-, pink-, and red-flowering plants in the proportion of one white to two pink to one red, i.e., one pure white to two hybrid white-red to one pure red (see Fig. 9). The conclusion is that neither the white nor the red heredity factor (gene) is completely dominant over its contrasting heredity factor. There are three varieties of Andalusian fowls. The feathers of one are splashed-white; the second variety has black feathers; and the third has blue feathers. Mating the black with the splashed-white produces only blue fowls. Neither the splashed-white nor the black dominates. Mating the blues with each other produces splashed-white–, blue-, and black-feathered fowls in the proportions of one splashed-white to two blue to one black. There is no complete dominance of heredity factors for splashed-white or for black in the characters shown by the blue-feathered hybrids.

In the breeding of short-horned cattle, crossing red-haired with white-haired produces cattle of an intermediate hybrid roan color.

Blending in size or form.—In addition to examples of blending inheritance of color of skin, color of feathers, and color of hair, we have evidence of a similar intermediate inheritance of form and size. Castle has produced evidence through experimental hybridization of rabbits showing blending in the length of ears, length and breadth of skulls, and the length of their long bones.

The explanation of blending or intermediate inheritance. It has been the belief of some observers that blending is a result of some other sort of heredity process than that which produces

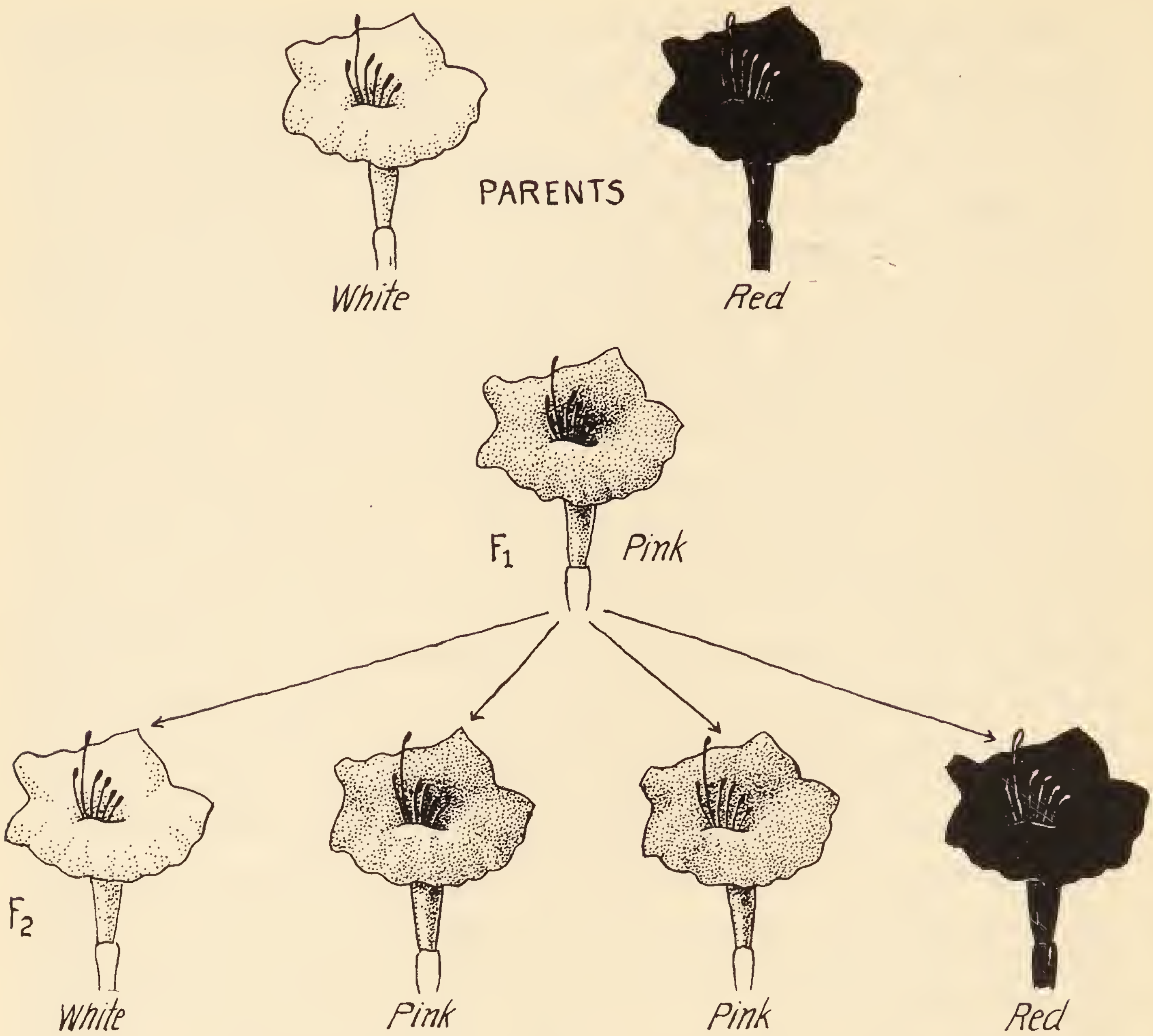


FIG. 9.—A cross between a white-flowered and a red-flowered four-o'clock giving pink in the F_1 generation, and one white, two pink, and one red in the F_2 (from Morgan, after Coireni). The pink offspring are examples of blending in heredity.

the Mendelian phenomena. But the number of observations of intermediate heritages that cannot be explained as products of the action of the processes that determine Mendelian heredity grows steadily less with the progress of inquisitive scientific genetic research. It is now the conviction of most authorities in this field that blending is a Mendelian product due (1) in some cases to a crossing between mates for contrasting characters, neither character being completely dominant, as in the case of the mating between white four-o'clocks and red four-o'clocks cited above; (2) in other cases (and these are the common cases) to matings between a carrier of single chromosome sets containing many heredity factors (genes) for a character (i.e., color of skin, feathers, hair or

fur; or size or form) and a carrier of similar single chromosome sets containing many heredity factors (genes) for the contrasting character. Such multiple factors may be present in one, several, or all the chromosomes of the single sets of chromosomes in the germ-cells of one or both mates. Thus intermediate inheritance may be due to the influence of multiple factors.

Examples.—The following examples of the processes by which multiple factors may determine blending or intermediate inheritance are patterned after those given by Castle.[1] A large race is made up of individuals, every one of which carries haploid germ-cells whose chromosomes contain many genes (i.e., multiple-heredity factors) whose combined influence determines large size of offspring. A small race is made up of individuals every one of which carries similar chromosome sets containing many genes whose combined influence determines small size. The multiple factors (many genes) for size are present in several, perhaps all, the chromosomes of the germ-cells of both races. When a member of the large race mates with a member of the small race, neither mate furnishes genes that dominate for largeness or smallness. The hybrid offspring are of intermediate size. But those hybrid offspring will produce sperms and ova equipped with an independent segregation of different genes for largeness and smallness. Matings of these hybrids will produce some individuals with a majority of genes for large size and other individuals with a majority of genes for small size, though more commonly they will carry both kinds of genes in equal number.

> . . . . extreme segregates containing only genes for large size or only genes for small size will be less common, the greater the number of contrasting genes in the preceding generation. Thus with only one contrasting gene, the second generation distribution would be in the ratio of one large size : two intermediate size (blended) : one small size. With two contrasting genes in the second generation the distribution would be numerically in five classes in the proportion of 1 : 4 : 6 : 4 : 1. With as many as six contrasting genes the second generation distribution would extend in a normal distribution, such as characterizes so-called "continuous" variation over a total of thirteen classes and only 1.5 per cent of the individuals would be pure line gene carriers and so complete segregates for either small or large size. A second generation population of over 4000 individuals would have to be produced before one could expect to recover a single full segregate for either a large or a small size.[2]

[1] W. E. Castle, *Genetics and Eugenics,* pp. 250–62.

[2] Castle, *op. cit.*

CHAPTER V

CYTOLOGICAL ORIGIN OF THE PRINCIPLES THAT DETERMINE THE HYGIENE OF HEREDITY

Orientation.—In the preceding chapter we called attention to the empirical, statistical, and experimental hybridization origins of our knowledge of the principles of the hygiene of heredity. The most important and the most recent source of our knowledge of these principles is furnished by scientific researches on the behaviors of germ-line cells (cytological research) before, during, and after fertilization; particularly the cytological researches which are associated with statistical investigations and experimental hybridization.

Fertilization.—We have noted on a previous page that the life of every plant or animal begins as a single cell and that the life of every sexual plant or animal begins with the union of a male germ-cell—a sperm—and a female germ-cell—an ovum (see Figs. 10, 11, and 12). We refer to the germ-cell formed by this union of sperm and egg as a fertilized ovum (see Fig. 13).

The heritage of the fertilized ovum is received from the heredity transmitted jointly by the union of the two living parental germ-cells (a father cell and a mother cell) of which it is formed. The cytoplasm of the fertilized ovum is a combination of the cytoplasm of the egg and the cytoplasm, much less in amount, of the sperm. It contains all the living, self-perpetuating organs and all the other structures present in the cytoplasms of both. Similarly, the nucleus of the fertilized ovum is a combination of the nucleus of the egg and the nucleus of the sperm. All the living, self-perpetuating organs and all the other structures of each nucleus are present in the union of the two nuclei that formed the nucleus of the living, self-multiplying (or self-dividing) fertilized ovum.

We have noted above that a careful microscopic examination of an enormously large number of protoplasmic cells has proved that every cell contains a nucleus or nuclear material. Because of such investigations we now know that the nucleus of every cell that divides into two cells passes through a stage in which it is composed of rod-like structures to which the name "chromosomes" has been given. On later pages we will discuss the chromosomes in some detail. It is important to note here that every species of plant

or animal has a characteristic number of chromosomes in all the nuclei of all the somatic-line cells and of all its germ-line cells except the mature germ-line cells—the sperms and ova. The sperms and ova contain in their nuclei only half the number of chromosomes present in all the other cells of the species.[1] The garden peas of Mendel carried seven chromosomes in their sperms and ova and fourteen chromosomes (seven pairs) in all their other cells. The fruit fly (*Drosophila melanogaster*), with which Thomas Hunt Morgan has done so much remarkable work, has eight chromosomes (four pairs) as its species number and four chromosomes as its sperm-and-ovum number. It is common practice to refer to the species number as the "diploid number" and the mature germ-cell number as the "haploid number."[2]

Fertilization (conception) is the union of a haploid maternal germ-cell with a haploid paternal germ-cell. Fertilization thus produces a single cell—the fertilized ovum—with a species number (i.e., a double number) of chromosomes characteristic of the species to which the parents belong. Thus fertilization is a process that brings together heredities transmitted from two parents. The paternal germ-cell, the sperm, is the only carrier of the heredity that the father transmits; the maternal germ-cell, the ovum, is the only carrier of the heredity the mother transmits. The fertilized ovum contains all the heritage that is received by the individual—the child—whose life began when the two parent cells united in fertilization. There is no other way.

Fertilization is a part of the process of reproduction. The living fertilized ovum, having the power of reproduction by dividing itself into two new cells—each with similar powers of reproduction—begins the life of a new individual thus possessed of inherited potentialities for growth, development, specialization, health, and longevity, and also of the possibilities of deficiency, defect, and disease, and, fortunately, defense against disease.

But fertilization and the fertilized ovum it produces must not be looked upon as independent facts. Here, as in all other details of life, there is an utter dependence of the life of the organism, from its very beginning, upon the favor of its essential experience

[1] An exception to this rule is found in connection with the sex chromosomes of certain organisms. See text below.

[2] "Haploid" comes from a Greek word meaning "single"; "diploid," from a Greek word meaning "double."

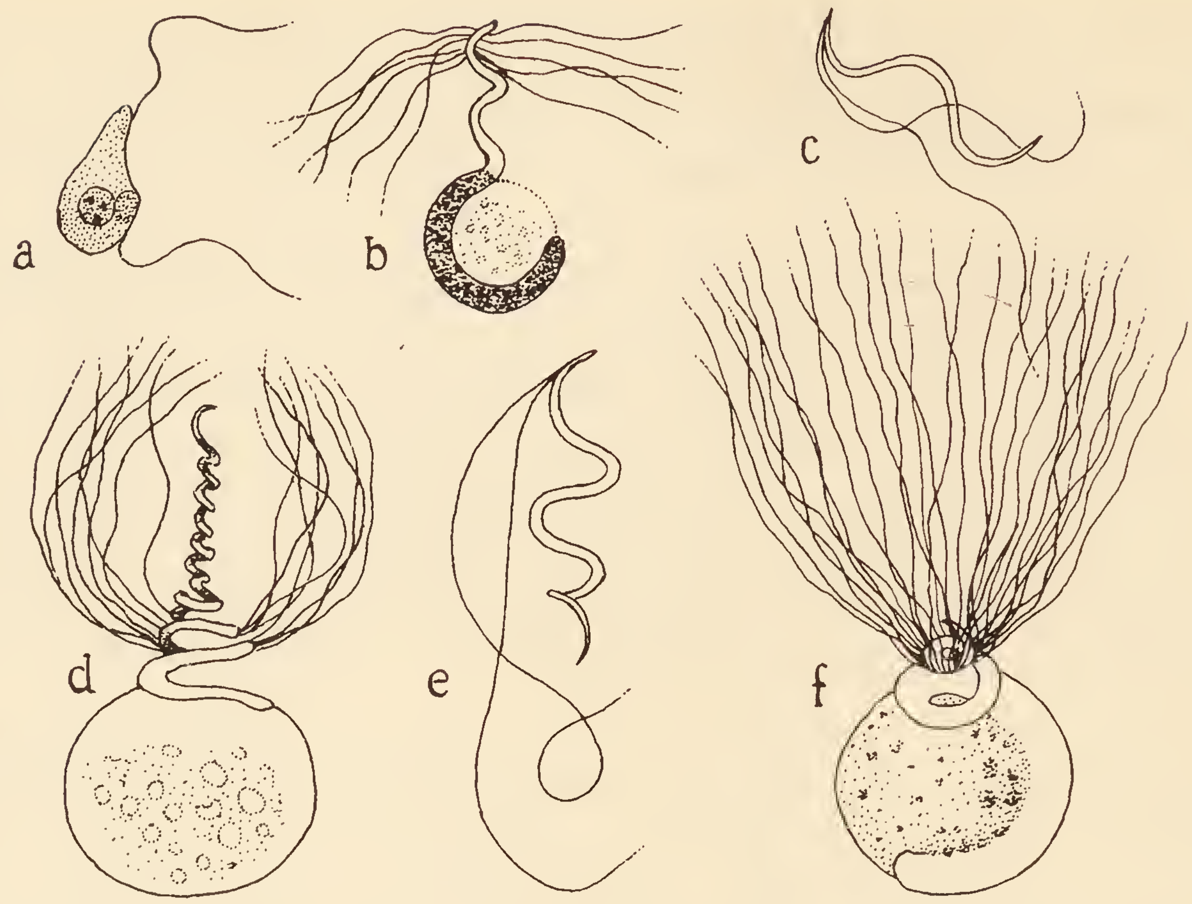


FIG. 10.—Sperm-cells (male gametes) of plants: *a,* marine alga; *b,* fern; *c,* moss; *d* and *e,* liverwort; *f,* fern (*a, c, d,* and *e* after Guenard; *b* and *f,* Strasberger; redrawn after Wilson).

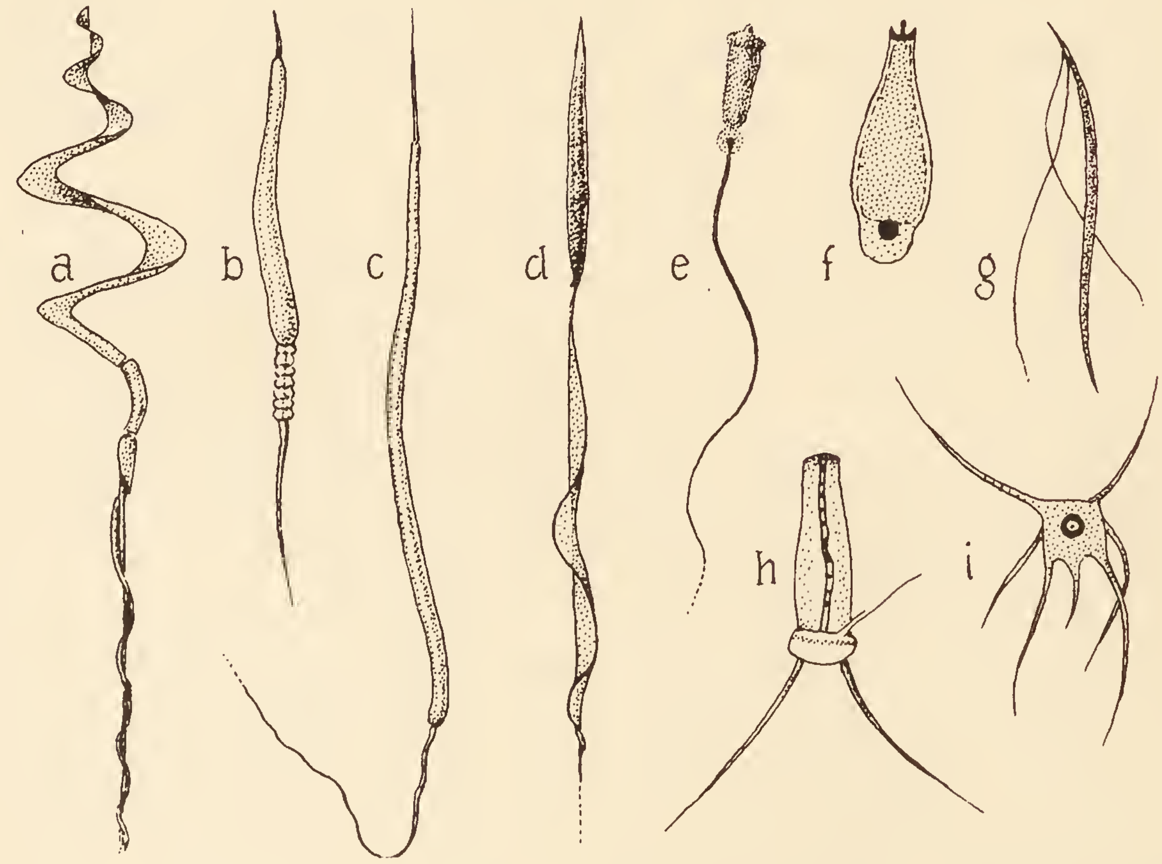


FIG. 11.—Animal sperms (male gametes of animals): *a,* bird; *b,* turtle; *c,* frog; *d,* toad; *e,* fish; *f,* round worm; *g,* flat worm; *h,* lobster; *i,* crab (after Wilson).

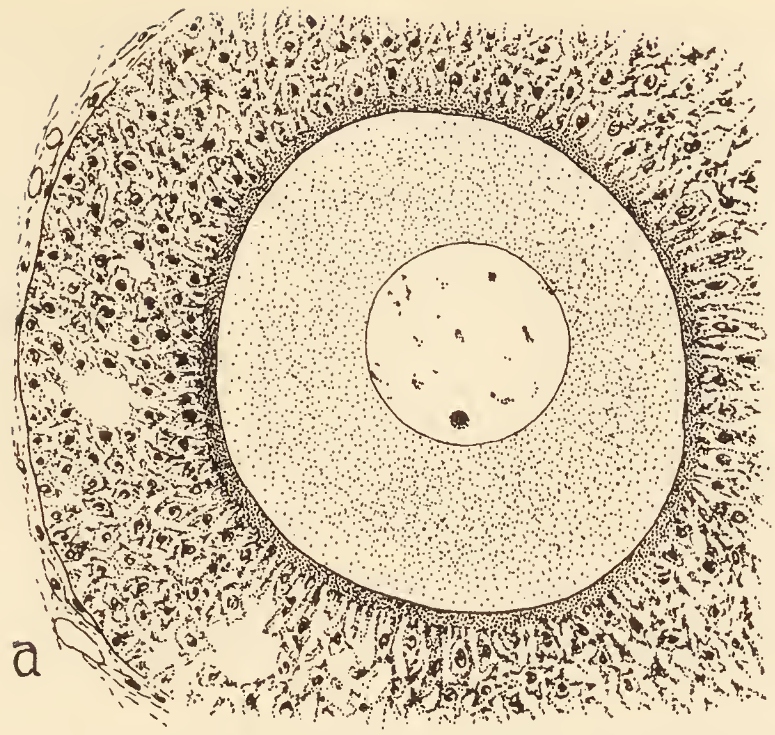


FIG. 12.—Human egg (cross section) and sperms. The egg, *a,* is surrounded by follicle cells which are shed as egg bursts from the ovary. In *b,* the smallest sperms are of the same magnification as the egg. (After Neves.)

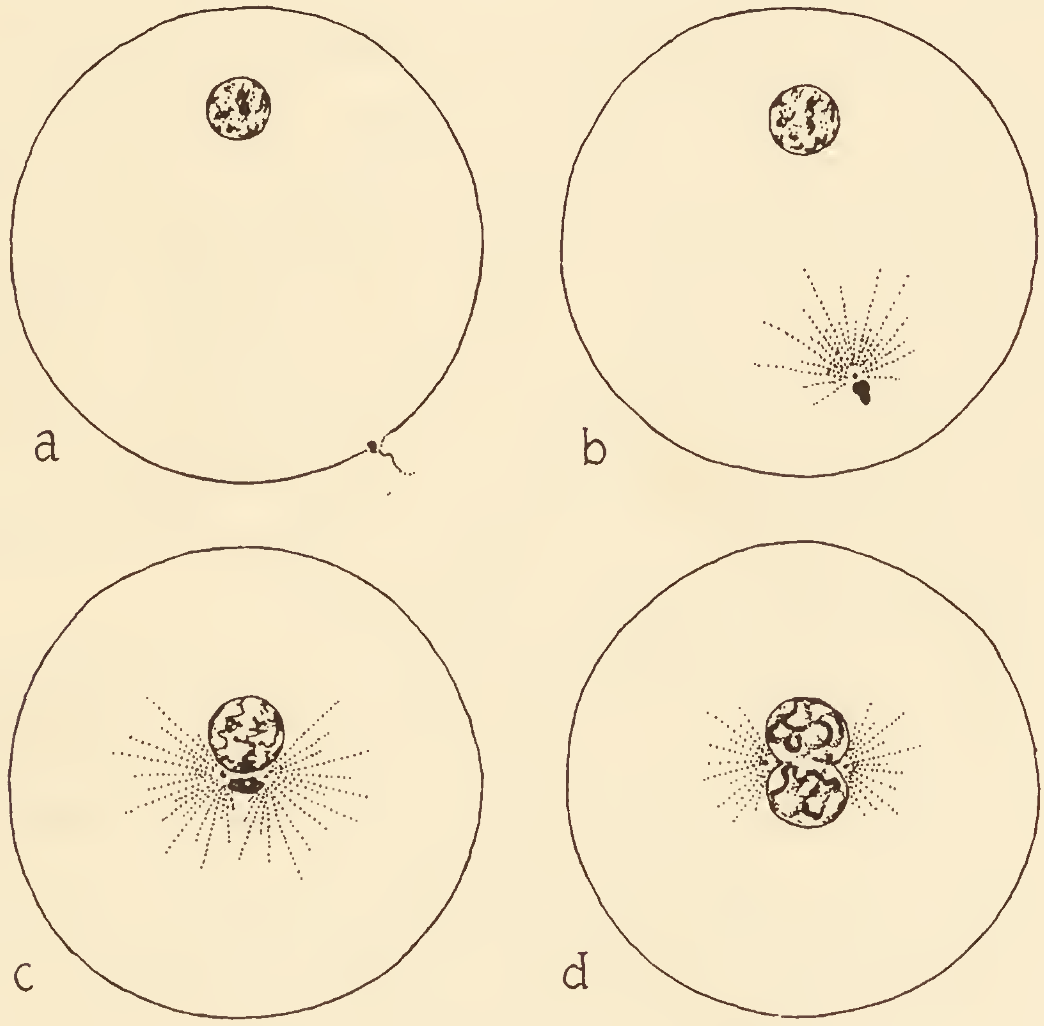


FIG. 13.—Fertilization of an egg: *a,* entrance of sperm; *b,* growth of the sperm nucleus (black), and early stage of spindle formation by the centrosome (central body); *c,* contact of sperm nucleus with that of the egg; *d,* fusion of the two nuclei.

with the favor of its essential environments. This essential relationship determines the life of the sperm, of the ovum, and of the fertilized ovum which they jointly form.

Reproduction.—Thus we note that the physiological union of two mature germ-cells, the ovum and the sperm, constitutes fertilization and forms the fertilized ovum. This union is initiated by the entrance of the sperm into the cytoplasm of the ovum. Reproduction is initiated by the first division of the fertilized ovum, producing two daughter-cells (its first mitosis). These two daughter-cells mark the beginning of the life of the embryo.

The embryo and its somatic-line cells and germ-line cells.—From the repeated divisions of the living cells of the embryo come two lines of cells. One is the somatic line, the other the germ line (see Fig. 20, p. 93). The somatic-line cells form the structure of the tissue and organs that constitute the body (i.e., bones, muscles, nerves, etc.). The germ-line cells, when they mature, furnish the sperms or ova with which may be formed a new individual with a new life and a new heritage. In mankind, the germ-line cells are present in the gonad glands of the testes of the male and of the ovaries of the female. After about two hundred and eighty days of repeated cleavages (divisions) and their accompanying adjustments, the human embryo under normal conditions becomes a newly born infant. The fertilized human ovum exists as a single cell only for a matter of minutes. When it is replaced by its two daughter-cells it disappears as an individual cell. It has become two individual cells that constitute the first cells of the embryo, the multiplication and development of which eventually produce a man or a woman, built out of somatic cells and furnished with the custody of germ-cells.

Mitosis.—Under the high-powered microscope it may be seen that the living cell is in a state of internal activity. The cytoplasm and the nucleoplasm are thus seen seething and streaming in currents that eddy and whirl in continuous turbulent change. This internal commotion of the living protoplasmic cell is a part of the physical chemical activities that perform the functions of the cell. What we see is visible evidence of orderly interrelated biophysics and biochemistry building the living protoplasmic structure of the cell, manufacturing its secretions, producing its heat, doing its work, forming its waste products, and serving its other living purposes, including growth, development, specialization, adapta-

tion, and reproduction. We referred to the functions of the cell on a preceding page. They are the basis of the total integrating functions that determine the life and health of the individual of whom the cell under observation was a part.

Among the most amazing of the movements within the cell that may be studied under the microscope are the orderly changes that take place in the nucleus and cytoplasm of the fertilized ovum that lead to its division into two living daughter-cells. The same orderly changes take place in these two daughter-cells (the beginning of the embryo), dividing them into four cells. This process of division of each new cell into two cells proceeds until enough cells are produced to form a mature plant or animal of the sort that furnished the egg and the sperm that united to form the fertilized ovum with which these repeated divisions began. Certain cells in the plant and in the animal continue to divide into new cells by this process as long as the plant or animal remains alive. Other cells cease to divide after a while. Their energies are then devoted wholly to other functions than cell-division. This function of cell-division is known as "mitosis." Mitosis is a physiological process of cell-division essential to reproduction and to the transmission of heredity and to the growth, development, and functional activity of the individual, plant, animal, or human being.

Investigation of the sperm-cell discloses the fact that it is composed almost wholly of a nucleus. It has very little cytoplasm. The nucleus is composed almost wholly of chromosomes. The egg is composed of a relatively large amount of cytoplasm as compared with the sperm. Its nucleus is also formed almost wholly of chromosomes. The union of the sperm and the egg produces a nucleus in the fertilized ovum that contains all the chromosomes of both germ-cells. The nuclei of all fertilized ova, all somatic-line cells, and all immature germ-line cells of a single sort of plant or animal in general contain the same number of chromosomes (the diploid number or species number). We have noted that this number is the sum of the number of chromosomes in the nucleus of the mature male germ-line cell, the sperm, added to the number of chromosomes in the nucleus of the mature female germ-line cell, the ovum. It is reasonably accurate to state that the mature germ-line cell (the sperm or the egg) contains half the number of chromosomes present in any of the other cells of the plant or animal of which the mature germ-line cell is a part.

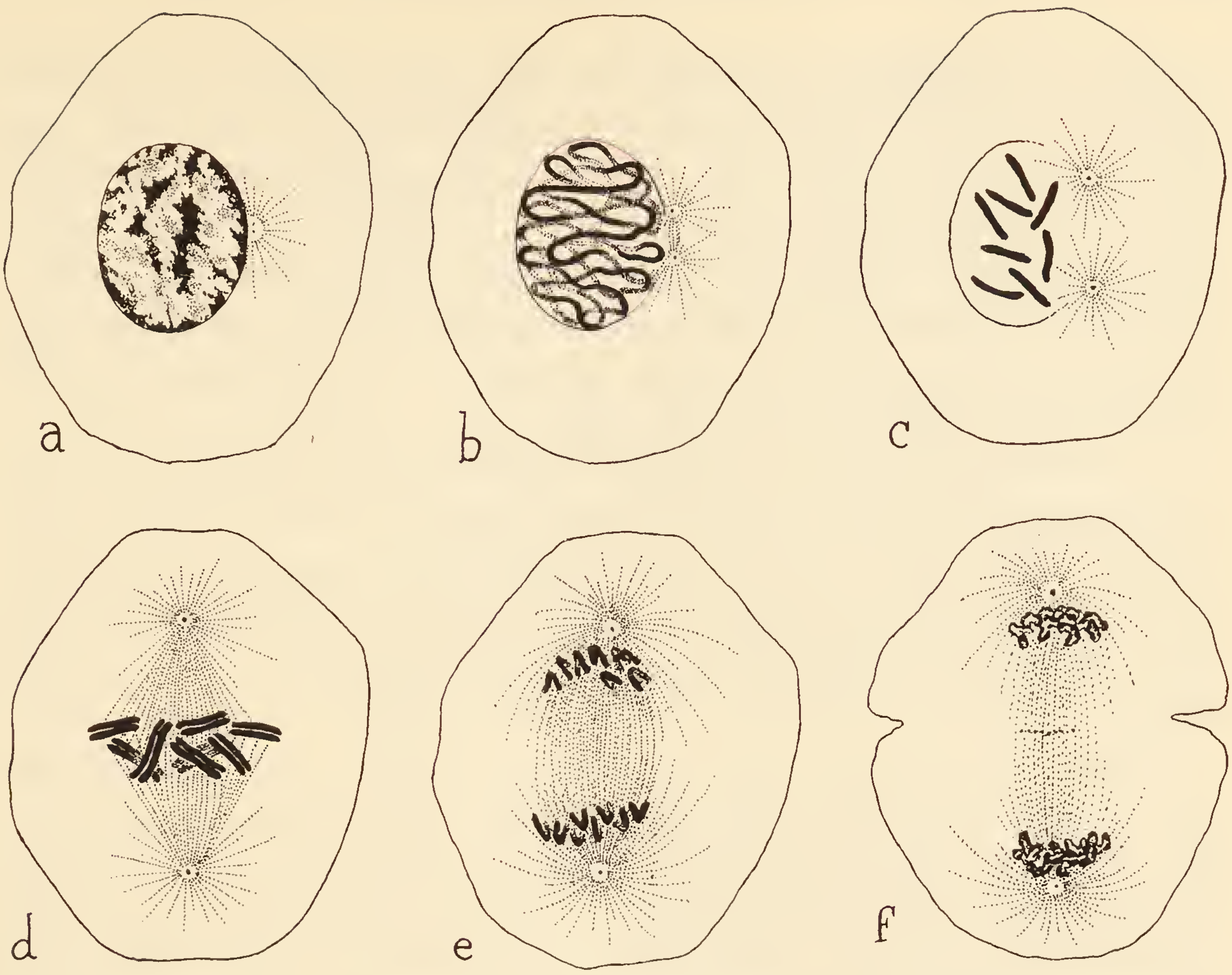
Thus, when a sperm-cell fertilizes an egg-cell it brings a haploid number of chromosomes to the egg nucleus which has its own haploid number of chromosomes. The fertilized ovum thus contains a double number of chromosomes, the diploid number, characteristic of the parental species. After patiently counting them under all the varied circumstances of mitosis and meiosis and after comparing many such observations for each species, we have a reasonably accurate record of the haploid and diploid number of chromosomes characteristic of many plants and animals.[1]

The phases of mitosis.—The phenomena of mitosis have been studied with great patience and safeguarding care by many highly trained investigators. The accurate knowledge that has been furnished by these men and women enables us to discuss mitosis in a series of five phases: (1) interphase, (2) prophase, (3) metaphase, (4) anaphase, and (5) telophase (see Fig. 14).

1. *The interphase of mitosis.*—This stage is usually described as the "resting" phase of mitosis. It is in reality an active stage because the living cell is never at rest. Perhaps it would better be known as the stage of relative rest. It is the period in which the cell nucleus ordinarily shows no evidence of chromosome forms. A reticular network may be seen. The central body or bodies (there may be one or there may be two), when present, lie in the cytoplasm or they may lie within the nucleus during this phase.

2. *The prophase of mitosis.*—This is a state of preparation. The reticulum becomes a thin, thread-like structure, known as the spireme. If there has been only one central body, that body divides into two central bodies, one of which moves toward one pole and the other to the opposite pole of the cell. The nuclear membrane disappears. The central bodies send out ray-like fibers, the "astral rays," that finally reach the equatorial plane or even cross beyond it. The two central bodies and their astral rays constitute the spindle formation that is characteristic of mitosis. The spireme thickens and segments into chromosomes. The chromosomes move toward the equatorial plane midway between the central bodies. This movement is described as a process in which the spindle fibers sometimes appear to push the chromosomes toward the equatorial plane. The arrival of the chromosomes in the equatorial plane completes the prophase of mitosis.

[1] See Edmund B. Wilson, *The Cell in Development and Heredity* (Macmillan, 1925), pp. 853–68.



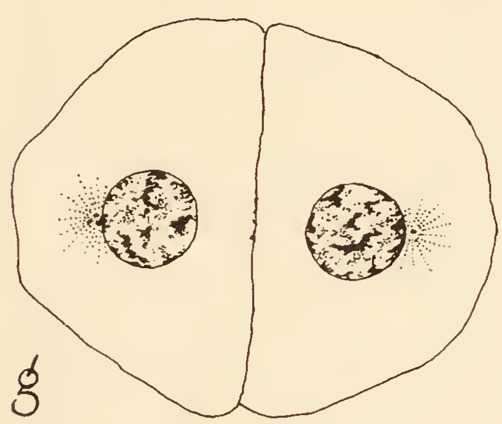


FIG. 14.—Diagrams of ordinary cell-division by mitosis: *a,* "resting" nucleus and centrosome; *b* and *c,* formation of chromatin thread (spireme) and then the formation of distinct sections (the chromosome); *b* and *c* are in prophase. In the metaphase, *d,* the centrosomes (central bodies) give rise to a spindle (the astral rays), and the chromosomes which have split longitudinally are grouped along the equator of that cell. In the anaphase, *e,* the halves of the original chromosomes are separated and drawn to opposite poles, whereupon they enter into the telophase, *f,* forming two new cells, *g* ("daughter-cells"), that grow to their normal cell size and assume the "resting" state.

3. *The metaphase of mitosis.*—This stage of mitosis accomplishes a result of dramatic and determining significance in its influence on the heredity about to be transmitted to two daughter-cells. Each chromosome in the metaphase splits longitudinally into two halves that are *exactly equal, quantitatively and qualitatively.* The "new" chromosomes thus formed appear to be attached to the spindles radiating from the central bodies and drawn by them, one half toward the central body at one pole and the other half toward the central body at the other pole.

4. *The anaphase of mitosis.*—The "new" chromosomes thus migrate from the equatorial plane of the cell to the opposite poles of the cell. Perhaps they are pulled in that direction by the spindle fibers radiating from the central bodies. Each of the two migrating groups of chromosomes is precisely the same as the other in number of chromosomes and in quantitative and qualitative character of each chromosome in one group as compared with its other chromosome half in the other group.

5. *The telophase of mitosis.*—While the two groups of new chromosomes migrate toward their respective poles, the cytoplasm of the cell begins to constrict equatorially between two poles. The chromosome groups as a rule lose their chromosome forms on reaching their poles, taking on the appearance of interphase nuclei.

The constriction of the cytoplasm proceeds until it divides the cell into two separate "daughter-cells" in which the cytoplasms may or may not be quantitatively and qualitatively alike, but each has a nucleus with chromosomes and a central body exactly like those of the nucleus of the other. The chromosome contents of the two nuclei are identical because of the precision of the longitudinal splitting of the chromosomes in the metaphase of the preceding mitosis. The cytoplasmic contents of the two cells differ because of the unequal division of the cytoplasm quantitatively or qualitatively during the preceding anaphase and telophase.

The central body.—The central body is a very significant part of the living structure of the cell. It is not always microscopically evident but may, nevertheless, be a constant part of the cell even though invisible at all times in the cells of some forms of life. The central body in many sorts of organisms has been observed in processes of growth and division, maintaining its identity in the interphase. It sometimes divides into two bodies during the telophase so that the two are present in the interphase and are immediately available for participation in the division of the daughter-cells. Thus the central body may be and probably is a cell organ that is reproduced from generation to generation as a living member of the group of organs of the cell that performs the functions of mitosis. The central bodies have other cell functions that need not be discussed at this point.

We know a good deal about the significance of the phases of mitosis and the behavior of the chromosomes in relation to the

principles of heredity and to the principles of hygiene that they determine. We know nothing about the specific parts played by the central bodies, or the other self-reproducing cell organs, in the determination of hereditary characteristics or qualities. We do not know the parts they play in growth, development, or specialization; but the probabilities are that they serve profoundly significant biological purposes.

Cleavage planes.—One of the most important factors, if not the most important factor, that determines growth in terms of cell mass, form of cell mass, and shape of organs and of organisms is furnished by the planes of cell-division in mitosis. If all the divisions of the progeny of a fertilized ovum were in the same plane, the product would be a long line of single cells, or a number of shorter strings of single cells, or merely many unattached single cells.

If the divisions were alternating divisions in two planes at horizontal right angles to each other, the product would be a flat surface, one cell deep. But if the sequences of cleavages are in planes that are at alternating or at irregular sequences of divisions at horizontal and vertical right angles to preceding planes, there will result a mass of cells having three dimensions essential to the structure of multicellular organisms. There are other factors than the cleavage planes that influence the dimension and shape of growth that will be discussed in a later chapter.

Mitosis is obviously a process of fundamental importance. It is the only way in which one cell transmits itself and its heredity to new cells in the somatic line and in the germ line of the new individual. It furnishes a multiplication of cells and a sequence of division planes leading to growth, mass, form, and shape. It makes possible the development and specialization of body-line cells and, as modified by meiosis, germ-line cells as described below. It is essential to the realization of the potentialities of growth, development, and specialization of living human protoplasmic cells that lead to physical, mental, and social health, to maturity, and to longevity. But, like all living processes of the protoplasmic cell, and of all living things built out of cells, its life, growth, and development are utterly dependent upon its favorable heritage, its favorable environment, and its favorable experience with environment.

Amitosis.—This phenomenon of some cells is known also as

"direct division" and as "fragmentation."[1] It occurs chiefly in very specialized cells and cells that are losing their vitality. In amitosis there occur none of the phases described in mitosis. The nucleus divides without spireme or chromosome formation into two "new" nuclei.

The present conclusion is that amitosis plays no determining rôle in heredity, growth, or development.

Meiosis.—We have noted on previous pages that the nucleus of the sperm and of the ovum contains half the number of

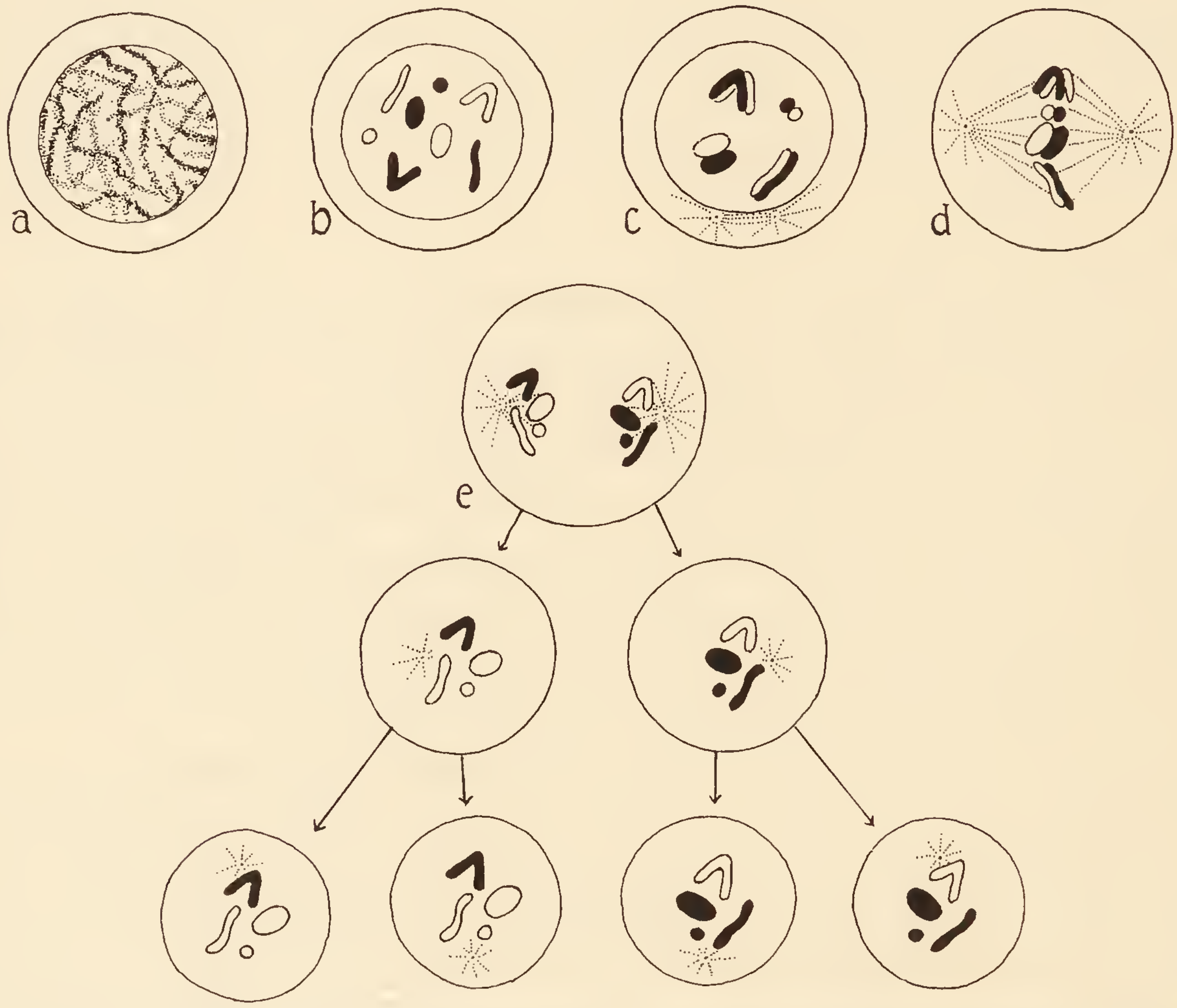


Fig. 15.—Diagram illustrating meiosis, or the reduction division. After the growth period (see Fig. 18), the maternal and paternal chromosomes pair (i.e., conjugate), then separate without splitting, each daughter-cell receiving one-half the usual somatic number (the diploid number) of chromosomes. The succeeding division is of the usual type of mitosis. In this diagram the black chromosomes are to be regarded as of one parental origin, the white from the other parent. The random assortment of chromosomes in *d* places three black chromosomes and one white chromosome facing one central body and three white chromosomes with one black chromosome facing the other. In *e* the chromosomes are in a random distribution consequent on the random assortment in *d,* so that in each pair of new cells produced are haploid cells, one cell of each pair containing three chromosomes from one parent and one chromosome from the other.

[1] See E. B. Wilson, *op. cit.,* pp. 214 ff.

chromosomes present in the germ-line cells from which those chromosomes came. The free mature egg and the free mature sperm are formed by preceding mitoses, the last two of which are so modified that the species number of chromosomes, the "somatic" or diploid number, is reduced to the haploid number in the nucleus of the sperm and of the ovum. This modification of mitosis reducing the number of chromosomes by one-half is known as meiosis or reduction division (see Fig. 15).

The phases of meiosis exhibit some modifications of mitosis that are of fundamental significance in their influence on heredity. They may be described as follows.

The prophase of meiosis.—In the prophase in meiosis the chromatin material (the reticulum) of the nucleus assembles in the form of two threads, precisely as in mitosis (see Fig. 16). One is composed of chromosome material from the mother; the other of chromosome material from the father. This thin-thread formation is known as the "spireme." The thin threads thicken and soon show that each is a series of chromosomes. The two threads lie side by side. The chromosomes thus lie in pairs. Each pair is composed of one chromosome of maternal origin and one of paternal origin. Each chromosome thread contains a haploid number of chromosomes. This pairing of chromosomes is known as synapsis. It is a pairing of mates, one of paternal, sperm-cell origin and one of maternal, egg-cell origin. There is only one mate for a given chromosome—no other chromosome can serve as that mate. The two mates are known as "homologous" chromosomes. The mates are in general of the same size and shape. The best known exception to this similarity is in the case of the X and Y sex-chromosomes of the human male. Much research has proved that they are qualitatively as well as quantitatively homologous, the two mates having the same sort of hereditary influence. So far the process is identical with the process of mitosis. But during synapsis in meiosis there may be an exchange of chromosome material between mates. This is a balanced exchange that so far as we know does not take place in ordinary mitosis. It is a conjugation between chromosome mates in which there is a balanced exchange of factors (genes) that participate in the determination of heredity (see Fig. 16).

The metaphase of meiosis.—In the metaphase in meiosis the chromosome pairs lie in the equatorial plane. Each pair, it must

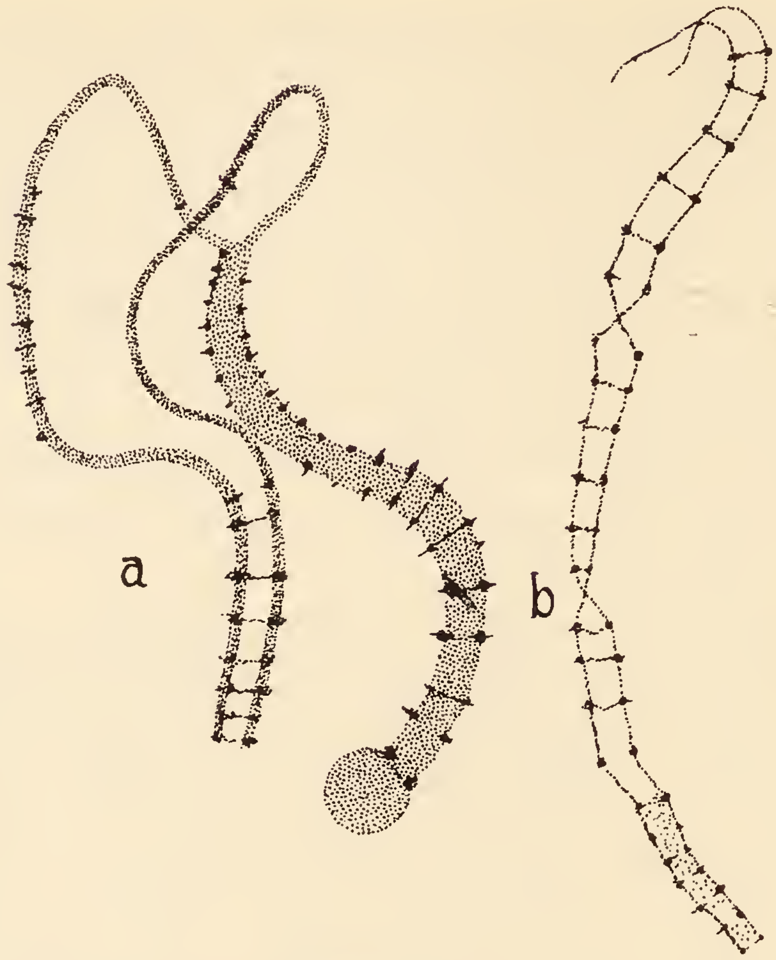


Fig. 16.—Synapsis showing conjugation or union of chromosomes of a flat worm. In *a* the two thin threads are coming together; in *b* there are indications at two levels of crossing over of the two united strands (after Morgan). Each strand (thread) is formed of a series of genes represented in the figure by darker points, with shaded connecting lines present when the two threads unite.

be remembered, is composed of one chromosome of maternal origin and one chromosome of paternal origin with such changes in their inherited content as may have been produced by the balanced crossing over of genes during synapsis in the prophase. The arrival of the chromosome pairs in the equatorial plane is accompanied by a random assortment of the pairs in so far as their facing toward the poles of the cell is concerned. This random assortment occurs only in meiosis. It does not occur in ordinary mitosis. It is a matter of chance whether the maternal mate or the paternal mate faces one pole or the other. This is a fact of the very greatest importance, particularly in the case of maturing germ-cells that have many pairs of chromosomes. The human germ-cell at this stage, having twenty-four pairs of chromosomes, may by chance assortment have any one of 16,777,216 chromosome arrangements.[1] As we proceed with our discussion, we

[1] Edwin Grant Conklin, *Heredity and Environment in the Development of Men,* fifth edition, revised (Princeton University Press, 1923), p. 174.

shall see the significance of this random assortment in relation to hereditary differences and individual differences between children of the same parents (see Fig. 17).

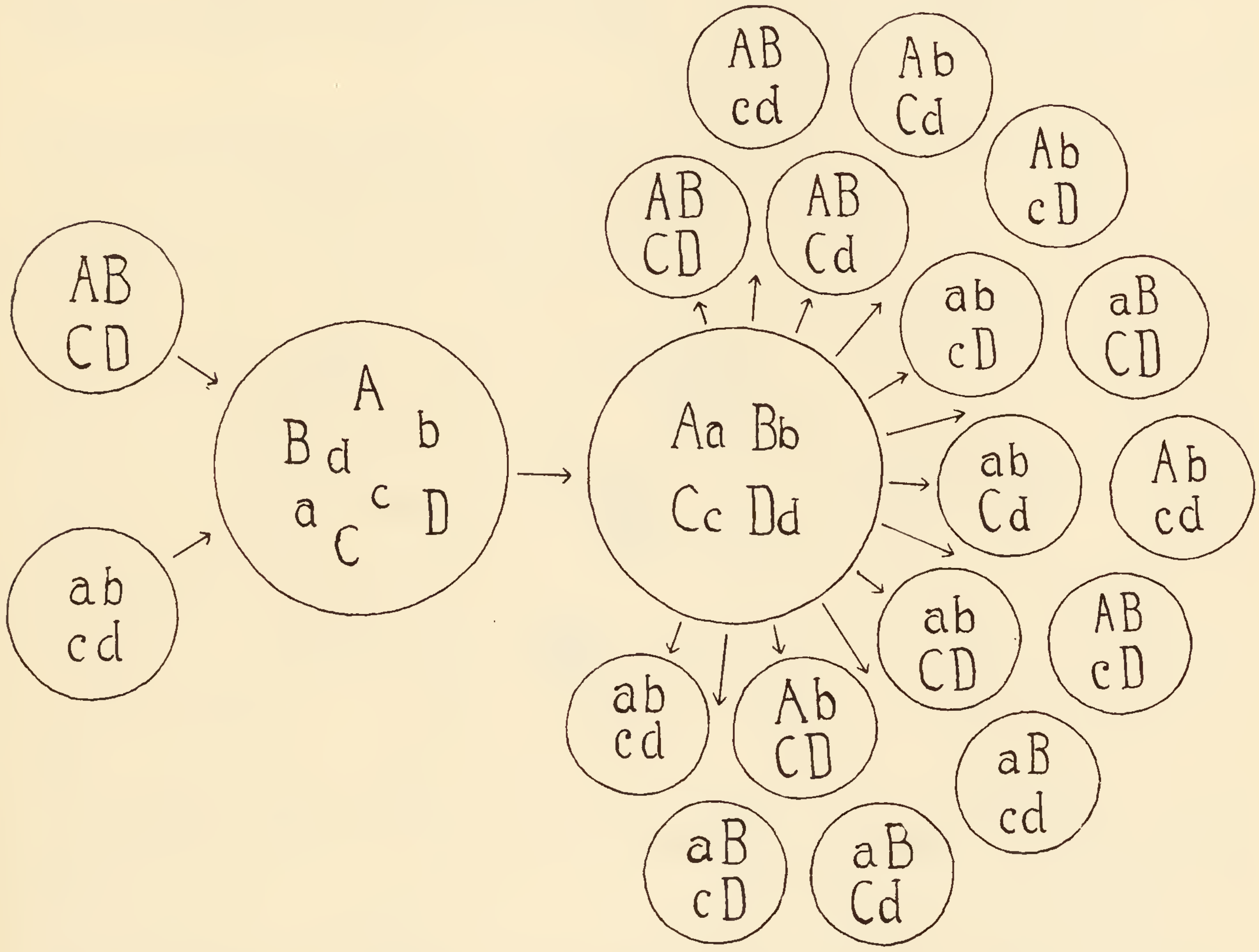


Fig. 17.—Diagram illustrating random assortment. The small circle containing the capital letters, *A, B, C, D,* represents an egg containing four chromosomes. The small circle containing the small letters, *a, b, c, d,* represents a sperm containing four chromosomes. The first large circle represents a fertilized ovum containing eight chromosomes contributed by the egg and the sperm. Thus this fertilized egg contains in the nucleus four maternal and four paternal chromosomes. Eight is the diploid number characteristic of every body-cell and every germ-cell produced by the repeated mitosis of this fertilized ovum up to the close of the growth period of the germ-cells (see Fig. 18). At the close of the growth period, the paternal and maternal chromosomes mate (see Fig. 16 for synapsis), *A* with *a; B* with *b;* etc. This mating (conjugation) is shown in the second large circle on the diagram above. In the succeeding division (meiosis) of that cell, there is a chance distribution of paternal and maternal chromosomes to the two new cells that are formed (see Fig. 15). There is the same chance distribution as there is in dealing eight playing cards. In the diagram above it is shown that with 4 pairs of chromosomes any one of 16 combinations is possible. With greater numbers of chromosomes, there are greater numbers of combinations possible. The 24 pairs of chromosomes in the human germ-line cells have a chance distribution of any one out of 16,777,216 combinations (see discussion of metaphase of meiosis, pp. 79 ff.). Random assortment is one of the compelling reasons for individual differences.

The anaphase of meiosis.—During this stage the chromosome pairs are separated, one member of each pair migrating toward one pole of the cell, the other member toward the other pole. Each chromosome may have already been split longitudinally. If not, such longitudinal division will occur without further delay, so that the telophase will furnish two pairs of new cells, each with a haploid number of chromosomes.

The migration of the chromosomes in the reduction division may involve a balanced exchange of broken-off parts of chromosome mates. There may be translocations of whole chromosome regions, larger quantitatively and qualitatively than the balanced exchange accomplished by crossing over in conjugation as described above. Such translocations of zones of genes must have the effect of varying the qualities and characters of the heredity carried by the chromosome mates that participated in the translocation. Thus variations of heredity within a species or family are produced by: the crossing over of genes during synapsis; the random assortment of chromosomes in the metaphase of meiosis; chemical changes of individual genes; and the translocation of gene zones during the early anaphase of meiosis. There are other causes of hereditary differences between the various members of a family and also between members of a species that will be considered later.

The telophase of meiosis.—The two final divisions of the germ-line cells of the male produce four sperm-cells, each containing a haploid number of chromosomes, all four of which are ready for fertilization.

The two final divisions of the germ-line cell of the female produce four ova, each containing a haploid number of chromosomes; but only one of these four ova can participate in fertilization. This one egg contains a relatively large amount of cytoplasm. The other three have very little cytoplasm and are incapable of successful fertilization.

Thus the end results of the two last divisions of meiosis are in the male four competent sperm-cells and in the female one competent egg-cell (see Fig. 18).

Summary.—The main facts of meiosis that furnish principles that determine the hygiene of heredity are:

Meiosis is a modification of mitosis that occurs only in maturing germ-line cells.

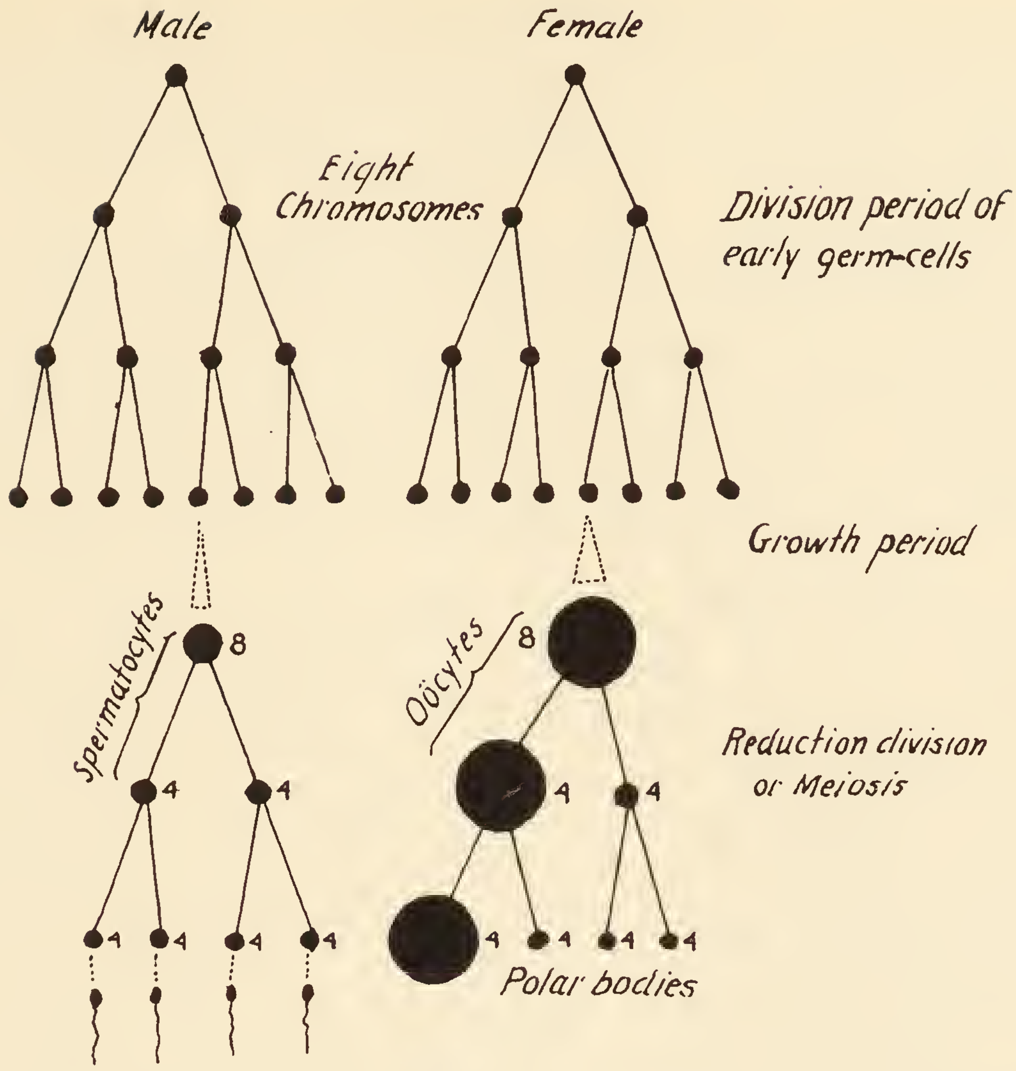


Fig. 18.—Diagram of the origin and behavior of male and female germ-cells (sperms and eggs). The primitive germ-cell (germ-line cell) of each sex undergoes many more divisions (mitosis) than are represented, whereupon each of the resultant cells by the addition of nutritive material grows in size. At this point the usual mitotic divisions are replaced by a conjugation (synapsis) of the chromosomes (see Fig. 16) and a reduction by one-half of the number of chromosomes passing into each of the two daughter-cells (see Fig. 15). The next division is normal. Four cells are produced in this process all of which become functional sperms, while in the female only one becomes a functional ovum (egg), the other three being rudimentary.

Meiosis prepares germ-line cells for participation in fertilization.

It is a preparation of germ-cells for participation in the transmission of heredity from parents to children.

It provides an enormous number of chances for hereditary differences between offspring.

These reduction divisions are essential to the transmission of heredity from two parents.

We shall later note other remarkable facts concerning the fundamental rôle played by meiosis in the determination of heredity.

CHAPTER VI

CYTOLOGICAL ORIGIN OF THE PRINCIPLES THAT DETERMINE THE HYGIENE OF HEREDITY (CONTINUED)

The chromosomes.—On preceding pages there are frequent references to the chromosomes and to the essential parts they play in the physiological processes of heredity and development. Our descriptions of mitosis, meiosis, and fertilization have marked the chromosomes as the most obvious of the cell organs that are concerned with the orderly achievement of those basic biological functions. A knowledge of the main facts descriptive of the chromosomes and their behaviors as living cell organs is requisite to the understanding of the principles of heredity.[1] While the importance of these "main facts" justifies their separate emphasis here, it is of importance also to stress again that no single organ, no group of organs, nor any organism can live independently. There is no such thing as a living chromosome separate from the living chromosome group of which it is a living part. Life and health of cell organ, cell, or organism are utterly dependent on favorable environment and favorable experience with favorable environment.

Discovery of chromosomes.—When Robert Brown observed the cell nucleus in 1831 and published his discovery in 1833, his contribution became part of a research program shared by many other investigators that has led to some of the most remarkable discoveries that have been made in the whole field of biology. These researches are being continued with unabated patience and ingenuity in some of the foremost laboratories of the world today.

We have noted that, late in the interphase, the nucleus takes on the appearance of a thin thread and that this thread during the prophase thickens and condenses into bodies that constitute the chromosomes. The name "chromosome" was used first by Waldeyer (1888) because these bodies stained so intensely with certain dyes.

Ancestry of chromosomes.—The accumulation of evidence furnished by observations made by many investigators proves that

[1] Many of the cytological data presented in this book have been suggested by the monumental publication of Edmund B. Wilson, *The Cell in Development and Heredity*, third edition (Macmillan, 1925).

in all the cells produced from a single fertilized ovum one half of the chromosomes are of maternal ancestry furnished by the ovum that was fertilized and the other half of the chromosomes are of paternal ancestry furnished by the sperm that fertilized the ovum.[1] This fact applies to every plant or animal that begins life as a fertilized ovum. This means that every somatic-line cell and every germ-line cell of a man or a woman, except the sperm-cells and ova, receives one half of its chromosomes from a maternal ancestry and the other half from a paternal ancestry. We have noted elsewhere that something like four thousand billion protoplasmic cells construct the body of an average man or woman. Each of those cells contains forty-eight chromosomes, twenty-four being of maternal source and twenty-four paternal.

Relation of chromosomes to Mendelian heredity.—The accumulation of evidence discovered through scientific observation of the behaviors of the chromosomes has finally proved beyond question that the life cycle of the chromosomes is responsible for the phenomena produced by the experimental hybridization with garden peas reported by Mendel. Evidence furnished by Montgomery, Boveri, Guyer, and others led up to statements by Sutton (1902–1903) and by De Vries (1903) that for the first time clearly described the behaviors of the chromosomes as biological processes that produce the phenomena of heredity observed by Mendel.[2] This relation of the chromosomes to Mendelian heredity will be discussed in further detail on later pages.

Nature of the chromosome.—The chemical composition of the living protein structure of the chromosome is not known. Its chemistry is a part of the chemical structure and chemical activity of the nucleus and of the protoplasm that constitutes the living cell as a whole. There can be no question that the chromosome molecules are characteristic and that, whatever the formulae may be that would describe them chemically, their structure, including, as it must, the chemical structure of the genes they carry, is fundamental to the chemistry of life.

Structure of the chromosome.—The researches of Taylor (1930), observing the very large chromosomes of *Tradescantia*

[1] See E. B. Wilson, *op. cit.*, p. 829, referring to the work of Van Benederi (1883–84) and Rabl (1885) and the "remarkable conclusion" of Boveri (1887).

[2] E. B. Wilson, *op. cit.*, p. 16.

and of other forms during mitosis, revealed an outer membrane for each chromosome. This membrane is described as containing "chromosomal sap" that surrounds a "long closely coiled thread known as the 'chromonema,' which may be the all-important gene line or at least its outer covering."[1]

Each chromosome appears to be formed of a series of much smaller segments known as "chromomeres," which in turn are formed of even smaller parts, known as "chromioles." The chromioles are containers of genes too small to be seen even under the highest-powered microscope. Figures shown by Hurst "after Wenrich" and "after Belting" show the chromosome pairs and chromomere pairs in the grasshopper (*Phrynotettix magnus*), and chromosome pairs, chromomere pairs, and chromiole pairs of the lily (*Lilium pardalinum*). The estimated number of chromomeres for a whole lily cell as shown in his Figure "34*a*" is 2,193.

Individuality of chromosomes.—A mass of evidence has been accumulated demonstrating that some of the chromosomes in plants and in animals display obvious individualities in size, shape, and behavior. These chromosomes may be recognized by their identifying characteristics when seen under the microscope. As a rule, the identity of the individual chromosome is lost when the nucleus is not undergoing mitosis or meiosis. But individual chromosomes have been identified in the resting or vegetative nucleus in exceptional cases. The number, size, and peculiarities of the chromosomes that disappear into the formation of a resting nucleus reappear in identical number, size, and peculiarity when the nucleus prepares for mitosis.

Montgomery in 1901 recognized the constancy of differences in the size and shape and in some cases the behavior of chromosomes of the same species.[2] His work proved the constancy of these objective evidences of individuality. Constant differences in the size and shape of chromosomes have been observed since in a great many groups of plants and animals. The differences in size are usually differences in the length rather than in the diameter of the chromosome. Among the chromosome forms noted are rod-shapes, V-shapes, J-shapes, enlarged ends, cross-sutures, trans-

[1] C. C. Hurst, *The Mechanism of Creative Evolution* (Macmillan, 1932), p. 44.

[2] E. B. Wilson, *op. cit.*, p. 834.

verse constrictions, and small spherical or spheroid forms. Sutton (1902) "found eleven recognizable pairs of chromosomes in the diploid groups of the male grasshopper, *Brachystola,* besides one unpaired X-chromosome."[1]

The typical behavior of chromosomes has been described on preceding pages in connection with the events of mitosis and of meiosis. The peculiar behaviors that characterize certain special chromosomes consist in retarded participation in mitosis, sometimes in evading certain phases of mitosis, or in other performances by virtue of which the individual chromosome may be recognized by its peculiar behavior.

Sex chromosomes: X- and Y-chromosomes.—We have noted in the preceding paragraphs that careful microscopic examination of the chromosome equipment of a species of plant or animal under varied experimental conditions enables the observer to recognize its individual chromosome members. He may become familiar with the size, shape, behavior, and even something of the gene content of each chromosome, particularly in those chromosome sets that are composed of a small number of chromosomes, as is the case with the fruit fly, *Drosophila melanogaster,* which has only four pairs of chromosomes in its diploid cells. The four chromosomes in a haploid group are numbered I, II, III, and IV (see Fig. 19). Every investigator of fruit-fly cytology identifies these four chromosomes in accord with a common understanding, so that there is never any question as to what chromosome is being described in a report of an investigator. As described by

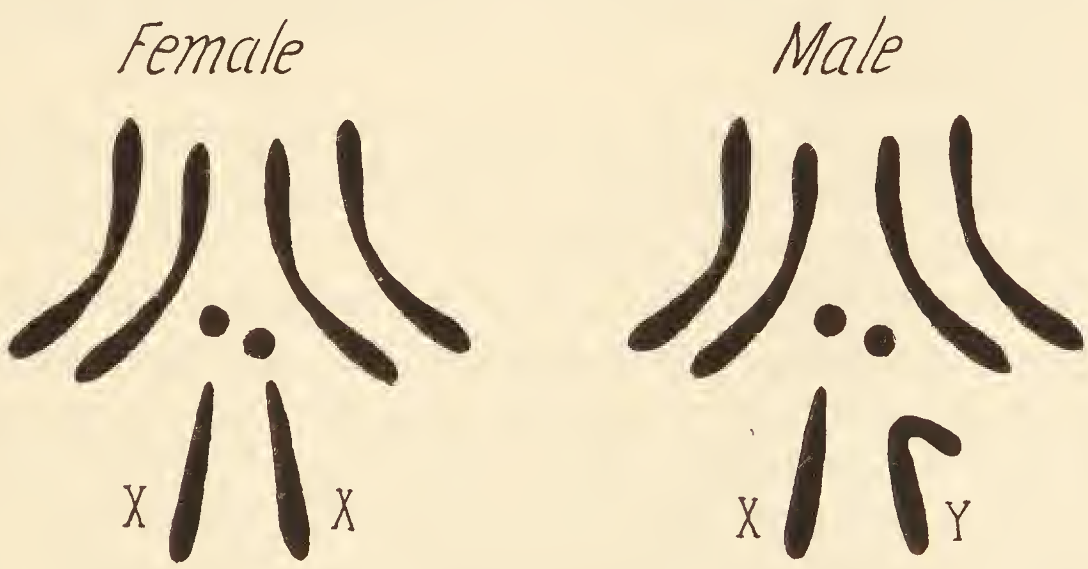


FIG. 19.—Chromosomes of the fruit fly (*Drosophila melanogaster*) (after Morgan).

[1] *Ibid.,* p. 837.

Morgan,[1] the first pair of the fruit-fly chromosomes are known as the X-chromosomes, of which two are present in the diploid cells of the female fruit fly. The male has only one X-chromosome. Its companion is known as the Y-chromosome, and is easily distinguished from the X-chromosome because of its difference in size and shape. The second pair of chromosomes are characteristically bent. The third are slightly longer than the second and are also bent. The fourth pair are much smaller and are rounded or slightly elongated.

The X-chromosomes were described some years before their relationship to sex was discovered. In 1891, recording his observations on the bug, *Pyrrhocoris,* Henking reported a "peculiar chromatin element" which he designated as "X." The peculiarity he described was in the behavior of this chromosome during the anaphase of reduction division, when it did not separate or divide into two chromosomes as the other chromosomes did but, instead, passed to one pole of the dividing cell with no mate for the other pole, so that one of the two new cells produced by the division contained eleven chromosomes and the other twelve, including the X-chromosome. Chromosomes behaving similarly to the chromosome described by Henking were reported by numerous later observers, using various names with which to identify the chromosomes they described. McClung, some eleven years later (1902), was the first to state the significance of the X-chromosome and its behavior in relation to the determination of sex. In 1909, E. B. Wilson suggested the use of the term "X-chromosome" in place of the numerous terms that had appeared in the publications of students in this field.[2]

We now have proof that in man and in many other animals and in certain plants sex is determined by the presence or absence of the X-chromosome in the sperm.

Sex determination.—E. B. Wilson describes three main classes of sperm-cells in relation to the determination of sex. One type is characterized by the fact that half the sperm-cells contain one X-chromosome and produce female offspring, while the other half contain no X-chromosomes and produce male offspring. Wilson's second type is characterized by the presence of a Y-chromosome as

[1] Thomas Hunt Morgan, *The Scientific Basis of Evolution* (W. W. Norton & Company, 1932), p. 80.

[2] This reference is taken from E. B. Wilson, *op. cit.,* p. 748.

a mate of the X-chromosome. The male organisms in this class produce sperms carrying X-chromosomes and sperms carrying Y-chromosomes in equal numbers. The sperms carrying an X-chromosome produce females. The sperms carrying Y-chromosomes produce males. A large number of species belong to this group, man being one of the number. The third type of sex chromosomes described by Wilson is characterized by an X-chromosome that is made up of two or more components. This type includes complicated cases in which the X-element is a group of chromosomes that act together. The X-group, regardless of its constituent number, is a single group in the male and a double group in the female.[1] A further discussion of this type need not be attempted here.

The study of human chromosomes presents obvious difficulties. Nevertheless, we have learned a number of important facts about them. On preceding pages we have noted that the species chromosome number of the human race is forty-eight, and that this number is made up of twenty-four pairs of chromosomes. Thus, there are twenty-four pairs of characteristic chromosomes present in every one of the approximately four thousand billion living protoplasmic tissue cells that constitute a man or a woman. In a woman every one of the four thousand billion sets of twenty-four chromosomes contains a pair of X-chromosomes, one X-chromosome having been transmitted in the sperm and the other in the ovum that united to form the fertilized ovum with which the life of the woman began. In a man, every one of his four thousand billion sets of twenty-four pairs of chromosomes contains a pair of sex-chromosomes, one member of which is an X-chromosome and the other a Y-chromosome, the X-chromosome having been transmitted in the ovum and the Y-chromosome in the sperm that united in the formation of the fertilized ovum with which his life began. Unfertilized human ova never contain Y-chromosomes. They always contain X-chromosomes. Half the human sperms contain X-chromosomes, half Y-chromosomes. Fertilization by a sperm containing an X-chromosome produces a female child; fertilization by a sperm containing a Y-chromosome produces a male child.

To repeat: The chromosome equipment of the human male contains a pair of sex-chromosomes, one of which is an X-chromosome and the other a Y-chromosome. When the germ-line cells

[1] E. B. Wilson, *op. cit.*, p. 772.

of the gonad glands in the testes of the man pass through the process of meiosis, one half of the sperms produced carry X-chromosomes, the other half carry Y-chromosomes.

All the diploid cells of the human female contain a pair of X-chromosomes. When the diploid germ-line cells of the gonad glands of the ovaries undergo meiosis, all the ova produced contain X-chromosomes.

The chance unions between sperms, half of which carry X-chromosomes and half Y-chromosomes, and ova, all of which contain X-chromosomes and none of which contain Y-chromosomes, produce fertilized ova, approximately half of which contain a pair of X-chromosomes and half contain a combination of an X-chromosome and a Y-chromosome. The fertilized ova having a pair of X-chromosomes inherit female characters and develop into females. The fertilized ova having an X-Y pair of chromosomes inherit male characters and develop into males.

The Y-chromosomes are much less understood than the X-chromosomes. In some organisms, notably the fruit fly, the occasional absence of the Y-chromosome in the male is accompanied by sterility. It is known too that the Y-chromosome contains very few genes but that broken pieces of neighboring chromosomes may become attached to the Y-chromosome, in which case the Y-chromosome becomes correspondingly increasingly active in association with the added genes.

Sex-linked heredity.—The behavior of the X-chromosome in reduction division accounts for the fact that certain characters are sex-linked. The heredity factors (genes) carried by the X-chromosome act as dominants, as incomplete dominants, or as recessives. When two X-chromosomes are paired and a female is produced, the characters and qualities determined by the constituent maternal and paternal genes appear in accord with Mendelian laws. When an X-chromosome and a Y-chromosome are paired and a male is produced, the character and quality determined by the genes of the X-chromosome appear.

The most striking evidences we have of sex-linked heredity are shown by the inheritance of such diseases as "bleeding" (hemophilia), which are caused by recessive genes (heredity factors) carried by the X-chromosomes. In the rare case that lives, X-chromosomes carrying these pathogenic recessive genes are paired in fertilization and the consequent hereditary disease appears in the

girl child or woman if she lives long enough. Ordinarily, the sex-linked diseases do not appear in women because of the infrequency with which X-chromosomes from both parents unite recessive genes for such diseases. The sex-linked pathogenic genes are usually contained in only one of the two chromosomes, and are therefore dominated by the normal genes in the other X-chromosome. The son of a mother carrying an X-chromosome containing recessive genes for such a disease as bleeding may inherit that recessive gene and thus be a bleeder. All his daughters will carry X-chromosomes containing recessive genes for bleeding, but none of them will be bleeders unless the mother carried a double set of X-chromosomes containing recessive genes for bleeding, in which case the daughter or daughters would be bleeders in the class described above.

Chromosome linkage.—It has been found that chromosomes are sometimes linked together and maintain this association throughout meiosis, as well as mitosis. The X-chromosome and sometimes the Y-chromosome may be attached to another chromosome in its haploid group. Similar attachments may occur between other chromosomes. This linkage of the chromosomes explains the fact that certain hereditary characters sometimes remain in association from one generation to another. It accounts for the fact, too, that certain heredities may be transmitted through the female and be evident only in alternate generations of males. Sex-linked heredities have been demonstrated experimentally with mathematical precision for chromosome linkage as well as for gene linkage. The latter will be discussed in later pages.

Specific functions of chromosomes.—We now have ample evidence that each chromosome in a haploid group has functions that differ from those of every other chromosome in that same group. This fact is particularly obvious in the case of the X-chromosome in its determination of sex. There is proof, too, that the functions of a given chromosome in a haploid group are the same for that chromosome in every other haploid group of the same species.

Homologous chromosomes.—In diploid chromosome groups the chromosomes are in pairs, one member being of maternal origin, the other of paternal. The two chromosomes that constitute the pair are known as homologous chromosomes. They are qualitatively (functionally) similar, and are usually similar in size and shape.

Location of heredity factors (genes) in the chromosome.—The work of Thomas Hunt Morgan and his associates has added to our knowledge some of the most valuable and remarkable information we now possess concerning the chromosomes and the genes they carry. These inquisitive investigators have succeeded in locating several hundred of the levels or zones in the four pairs of chromosomes of the fruit fly (*Drosophila melanogaster*) in which occur the genes that determine specific hereditary characters. The results of these investigations have produced a chromosome map for the fruit fly that gives the location in its chromosomes of several hundred of these zones, each zone containing genes (or a gene) whose special influence on heredity in the fruit fly has been studied experimentally. It is estimated that the chromosome group of the fruit fly contains from 2,500 to 3,000 genes. Further reference to the work of Morgan and his school will be made in our later discussion of the genes.

We know now that the chromosomes that constitute the haploid group of a given species contain all the heredity factors, i.e., all the genes of heredity, that identify that species. The genes of a species are located in an orderly fixed sequence of zones in the chromosomes.

Life cycle of the chromosomes.—The life of the chromosomes from fertilization to fertilization constitutes a cycle the stages of which are constant and are characteristic of all sexual plants and animals. These stages occur in the life of the chromosomes in the germ-line cells. They occur in an orderly sequence, as follows: (1) a fertilized ovum is formed by the union of the chromosomes of two mature haploid germ-cells, a sperm and an ovum; (2) the life cycle of these chromosomes is continued in the mitosis of the chromosomes of the diploid fertilized ovum and the consequent cleavage of the ovum into two daughter-cells that by repeated subsequent mitoses and cleavages form the diploid germ-line cells and the diploid body-line cells that construct the consequent multicellular plant, animal, or human being as the case may be; (3) the life cycle of the chromosomes eventuates in the meiosis (reduction division of chromosomes) of the mature germ-line cells, forming thereby sperm-cells or ova having half the species number of chromosomes, thus completing the life cycle of the chromosomes carried by the sperm and ovum with which the cycle began.

Genetic continuity of the chromosomes.—The facts that have

been presented on preceding pages make it clear that the chromosomes that disappear into the "resting" nucleus that is formed at the termination of the telophase of mitosis and which characterizes the interphase reappear in the succeeding prophase in equal number and in general of the same sizes and shapes. Only in exceptional cases have the chromosomes been identified as such in the nucleus during the interphase of mitosis. They disappear from view in that stage because their structure becomes the reticular framework of the "resting" nucleus. This reticular structure of the nucleus disappears in the prophase because the reticulum is transformed into the thin threads—the spiremes—that condense and segment into the chromosomes of the late prophase of mitosis.

There is thus a genetic continuity of the chromosomes.[1] The chromosomes present in the sperm and the ovum become the chromosomes present in the fertilized ovum. The maternal chromosomes and the paternal chromosomes present in the fertilized ovum are the sources of similar maternal and paternal groups of chromosomes in every somatic-line cell and in every germ-line cell produced by mitoses and cleavages of the fertilized ovum. The maternal and paternal chromosome groups present in the germ-line cells are reassorted and distributed to the sperm-cells produced by meiotic divisions of the germ-line cells of the male or to the ova produced by the meiotic divisions of the germ-line cells of the female. The chromosomes of the ova and of the sperms are then available for union in fertilization (see Fig. 20).

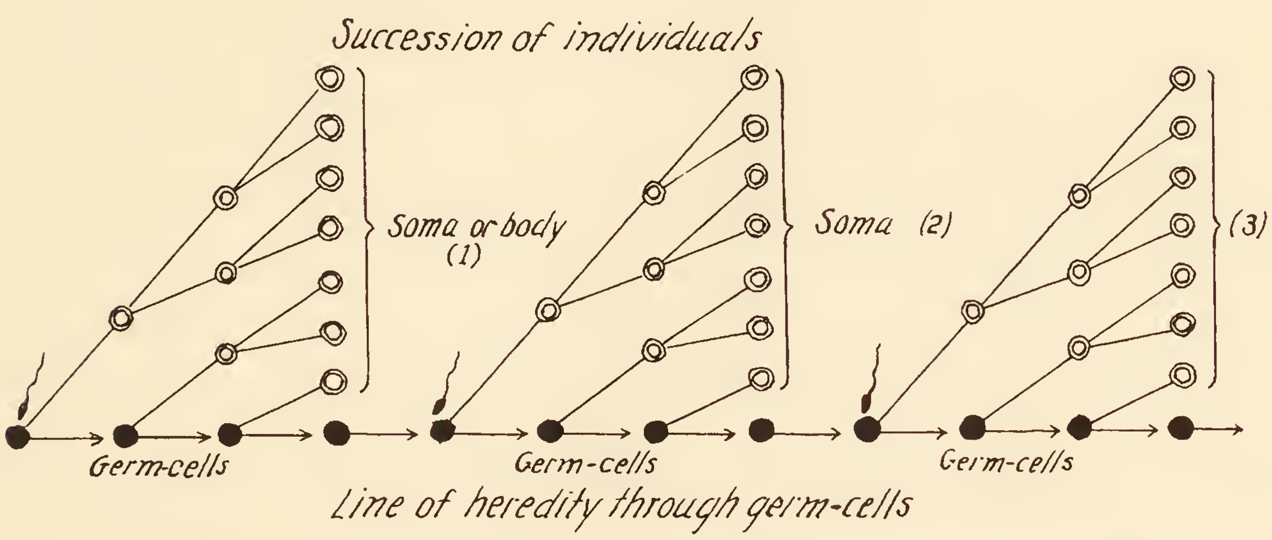


FIG. 20.—Diagram illustrating germ-line inheritance. The fertilized germ-cell gives rise to body-cells (somatic cells) and to new germ-cells. While the body dies at each generation, some of the germ-cells repeat the process. Hence, the stream of life flows through the germ-cell line.

[1] See E. B. Wilson, *op. cit.*, pp. 828–29, 890.

From the facts that have been presented describing the life cycle of the chromosomes, formed as it is by the behaviors of the chromosomes in fertilization, mitosis, meiosis, and again in the next fertilization, it is evident that every living chromosome in plant or animal has an immortal past and that every living germ-cell chromosome has the possibility of an immortal future. The chromosome heritage from the biological past goes back through a series of chromosome divisions of the one-celled organisms and through a series of chromosome life cycles in the many-celled metaphyta and metazoa to the very first chromosome ancestors with which life began many millions of years ago. The chromosome heritage of the infinite future is potential in the living germ-cell chromosomes of today, for they are the only possible sources from which those future chromosomes may receive by cell-division the chromosome fractions essential to their heritage of life and health.

CHAPTER VII

CYTOLOGICAL ORIGIN OF THE PRINCIPLES THAT DETERMINE THE HYGIENE OF HEREDITY (CONTINUED)

The genes: Definition.—Gregor Mendel's analysis of the results of his hybridization experiments led him to state that the phenomena he observed were products of the "internal composition of the egg and pollen cells." Our knowledge of that "internal composition" gained since the time of Mendel verifies his conclusion. We now describe various parts of that internal composition with such words as "cytoplasm," "central bodies," "nucleoplasm," "nuclear sap," "nuclear reticulum," "chromatin," "chromosomes," and "genes." We may describe their vital behaviors in relation to Mendel's hybridization experiments as "cell-division," "cleavage," "mitosis," "reduction division," "meiosis," and "fertilization."

Mendel concluded that "constant progeny can only be formed when the egg cells and the fertilizing pollen are alike in character so that both are provided with the material for creating quite similar individuals as is the case with the normal fertilization of pure species"; and further that it is ". . . . certain that exactly similar factors must be at work also in the production of constant forms in the hybrid plants."[1] We now know that egg-cells and pollen are "alike in character" and thus "provided with the material for creating quite similar individuals" only when their chromosomes and genes are alike in character.

Mendel wrote also that, "since the various constant forms are produced in *one* plant or even in *one* flower of a plant, the conclusion appears logical that in the ovaries of the hybrids there are formed as many sorts of egg cells and in the anthers as many sorts of pollen cells as there are possible combination forms and that these egg and pollen cells agree in their internal compositions with those of the separate forms. In point of fact, it is possible to demonstrate theoretically that this hypothesis would fully suffice to account for the development of hybrids in the separate generations if we might at the same time assume that the various kinds

[1] W. Bateson, *Mendel's Principles of Heredity* (Cambridge University Press, 1913); see translation of Mendel's original paper (read February 8 and March 8, 1865), p. 335. The text quoted above is on pp. 356 f.

of egg and pollen cells were formed in the hybrids on the average in equal numbers."[1] Bateson, in his footnote to these statements of Mendel, calls attention to the fact that they "contain the essence of the Mendelian Principles of Heredity."

Our knowledge of the internal structure and the physiological behavior of the egg and the sperm acquired since Mendel announced these conclusions enables us to state that the sorts of eggs formed in the ovaries and the sorts of sperm-cells formed in the pollen grains are determined by the sorts of genes present in the chromosomes of the germ-line cells of the ovaries and in the germ-line cells of the anthers; that the number of sorts of egg-cells or sperm-cells thus formed is determined by the random assortment of chromosomes in meiosis (reduction division); that egg- and sperm-cells are formed "on the average in equal numbers"; and that variety in heredity characters and qualities are due to combinations of similar eggs and similar sperms having many different assortments of chromosomes. We have noted that the germ-line cells of a man may produce as many as 16,777,216 assortments of chromosomes in his sperm-cells and that there is a similar number of possibilities in the production of different assortments of chromosomes in the ova from the germ-line cells of a woman.

In his *Life of Mendel,* Iltis writes that Mendel's "main thought" was "that what is handed on in inheritance is not a sort of generalized impression of the specific type but a number of individual characters or rudiments (heredity factors, genes) each of which is separately transmitted and that these individual characters rigidly and inalterably compose the image of the species . . . ." This in 1865 "was a new and uncongenial notion."[2]

And again, writing of the "Mendelian theory," Iltis states that in this theory "the heredity factors only enter into new combinations during the formation of the reproductive cells and in the process of fertilization, whereas in all subsequent nuclear divisions the heredity factors or genes pass from cell to cell in their totality."[3]

The use of the word "gene" to convey the meaning of heredity

[1] W. Bateson, *op. cit.,* pp. 356 f.

[2] Hugo Iltis, *Life of Mendel,* translated by Eden and Cedar Paul (Allen & Unwin, London, 1932), p. 177. Original publication, *Gregor Johann Mendel, Leben, Werk, und Wirking* (Julius Springer, Berlin, 1924).

[3] Iltis, *op. cit.,* p. 291.

factor dates from Johanssen in 1909. This word has come into universal usage since his time.

Location and nature of the genes.—A mass of scientific evidence, much of the most impressive of which has been furnished by Thomas Hunt Morgan[1] and his followers, has proved the existence of living entities within the chromosomes that function as heredity factors. These entities are the genes to which we have made frequent reference. Although they are too small to be seen with the aid of the most powerful microscope, the existence of what we call the "gene" is an established fact. The "exact detailed information" that has been furnished by experimental work of this sort carried on by Morgan and his school "has completely transformed the old speculations concerning the principles of heredity into the laws of genetics, and because of this verifiable information the study of genetics has become one of the most advanced fields of biological work . . . ."[2]

The careful work of Morgan and his collaborators has made possible the construction of the "maps" to which we have referred on previous pages showing the locations of approximately five hundred mutant genes in the four chromosomes of the fruit fly. These investigators have concluded that there are between 2,500 and 3,000 genes in the chromosome group of this fly.

Paternal and maternal genes.—The chromosomes of the egg-cell contain genes of maternal germ-line cell origin; the chromosomes of the sperm-cell contain genes of paternal germ-cell origin. The union of egg and sperm, bringing these two haploid cells together, produces a fertilized ovum—a diploid germ-cell—containing chromosomes and genes of paternal origin and an equal number of chromosomes and genes of maternal origin. The mitoses of the fertilized ovum and its daughter-cells produce a distribution of maternal and paternal chromosomes and genes to every somatic-line cell and every germ-line cell that constitute the body of the individual so produced.

The linear order of the genes.—Maps of chromosomes have been made, most notably of *Drosophila melanogaster,* the fruit

[1] See Thomas Hunt Morgan, *The Physical Basis of Heredity* (J. B. Lippincott, 1919), and *The Scientific Basis of Evolution* (W. W. Norton & Company, 1932).

[2] Thomas Hunt Morgan, *The Scientific Basis of Evolution,* p. 90.

fly.[1] These maps plot a uniform distribution of known genes in a linear order within the chromosomes.[2] The chromosomes have been likened to strings of beads,[3] each bead representing the location of a gene within the chromosome. It is perhaps more accurate to liken the sequence of the genes to a series of disks, or, better still, to a series of zones in the chromosomes.

The importance of this orderly linear distribution of genes resides in the fact that it necessitates an equal division of each gene quantitatively and qualitatively whenever the chromosomes are divided in mitosis. Thus, the two new chromosomes produced by a division of a chromosome are exactly alike, each gene of one member of the pair of "new" chromosomes produced being precisely like its other half in the other chromosome.

Somatic genes.—We have been discussing mainly the genes of the germ-line cells. The facts of chromosome and gene behavior in meiosis, fertilization, and mitosis of germ-cells make it inevitable that every somatic-line cell of the body thus produced shall contain two sets of genes, one set of maternal origin and the other set of paternal origin. The nucleus of every one of the thousands of millions of tissue cells that constitute a living human body contains two sets of chromosomes. Each set is composed of twenty-four chromosomes. Each chromosome of one set is like its mate in size, shape, and purpose in the other set except in case of the sex-chromosome (the X-chromosome) of the male, the mate of which is a Y-chromosome. The linear series of genes carried in each chromosome is identical, gene for gene, with the linear series of genes carried in its companion (homologous) chromosome. The only exception to this occurrence of genes in pairs is in the case of the genes of the X-chromosome in the body-line cells of the human male. The Y-chromosome, the mate of the X-chromosome, is different from the X-chromosome in size and shape, carries few genes, and performs different physiological functions.

Thus the muscle-cells, the nerve-cells, the gland-cells, the bone-cells, and all the other tissue cells of the human body have the same double chromosome group, a mother group and a father group,

[1] Thomas Hunt Morgan, *The Physical Basis of Heredity,* p. 118.

[2] Thomas Hunt Morgan, *The Scientific Basis of Evolution,* p. 90.

[3] See H. S. Jennings, *The Biological Basis of Human Nature* (W. W. Norton & Company, 1930).

and in consequence the same double linear series of genes. ". . . . differentiation of the cells of the body is not due to visible changes in the chromosomes or their number no matter how different the functions of the specialized body cells may be. It has also been practically demonstrated that all of the genes are present in every cell regardless of its specialization."[1] Thus Mendel's postulates stated on preceding pages have been verified in amazing detail.

Dominant genes and recessive genes.—Dominant and recessive characters and qualities are products of the influence of dominant and recessive genes. A pure-line heredity is a product of a union of an ovum carrying chromosomes containing genes that determine a given character or quality of offspring with a sperm carrying chromosomes and genes that determine the same sort of character or quality of offspring. A hybrid heredity is a combination of dominant and recessive genes, the characters or qualities that are determined by the recessive genes being hidden by those determined by the dominant genes.

Gene mutations.—When a member of a species of animal or plant differs from other members of the species in a single hereditary difference that is transmitted to his offspring, the new variety is in many cases due to a change, a mutation, of a gene or linkage of genes in a definite zone of a known chromosome. "Among domesticated animals and plants hundreds of types are accepted today as differing from one another by single hereditary differences—horses, cattle, sheep, pigs, rats, mice, guinea pigs, among animals; and wheat, rye, oats, sweet peas, garden peas, corn, tobacco, and a long list of other flowering plants."[2]

Morgan reports (1932) that over five hundred mutants are known in *Drosophila melanogaster,* the fruit fly, and that new mutants are "constantly appearing." He states that "most of these have been definitely shown to be point mutants" (i.e., gene mutants). The changes noted in the fruit or vinegar fly are evident in a variety of modifications such as wing characters, eye characters, and bristles.[3]

Nature of gene mutation:

1. *Translocation of genes.*—Laboratory observation proves that chromosome pieces may occasionally be broken off spontane-

[1] Thomas Hunt Morgan, *The Scientific Basis of Evolution,* p. 44.

[2] *Ibid.,* p. 33.

[3] *Ibid.*

ously during the late metaphase of meiosis. A chromosome piece may become attached to the next chromosome in the haploid series to which it belongs. The chromosome that receives the translocated piece becomes a longer chromosome by virtue of the addition. The chromosome from which the piece was separated becomes that much shorter. But the total number of genes is unchanged in the haploid group of chromosomes concerned. The relationship between the genes is altered. Short chains of linked genes may be altered. These changes in gene relationships lead to changes in the characteristics or qualities of the offspring influenced by the changed gene relationships.

It has been noted, too, that chromosome pieces may be translocated from chromosomes in one haploid group to chromosomes in its companion haploid group. Thus in 1924 "Stern described an attachment of a fragment of the Y chromosome to the spindle fibre end of the X chromosome."[1] The effect of translocations of chromosome pieces from one set of chromosomes to chromosomes in the companion set would necessarily decrease the total number of genes in the first group of chromosomes and increase the total in the receiving group. Corresponding changes in hereditary traits would then necessarily appear in the offspring produced.

2. *Duplication of genes.*—It has been noted also that in some cases of translocation "the broken chromosome pieces may be present in association with two normal chromosomes. This is called *duplication.* An individual carrying such a duplication has certain genes in triplicate and usually dies unless the piece is very small."[2]

3. *Deficiency of genes.*—A piece of chromosome may be lost during meiosis. "This is called *deficiency.* Such individuals have only one set of certain genes. If the deficiency is too big the individual dies as a rule, but if small it may live. It is interesting to note that for a given section deficiency is more likely to be disastrous than duplication."[3]

Causes of spontaneous gene mutation.—Laboratory observation has shown that changes take place spontaneously in the genes themselves without any recognized cause. It has been suggested that cosmic rays, radiation in the earth, climatic extremes, ex-

[1] Thomas Hunt Morgan, *The Scientific Basis of Evolution,* p. 81.

[2] *Ibid.,* p. 79. [3] *Ibid.*

tremes of temperature, soil differences, and food differences may serve as causes of spontaneous gene changes.[1] Morgan notes that "Muller and Mott-Smith have shown that the amount of radiation in the earth is inadequate to account for the ordinary process of mutation in *Drosophila*."[2]

However, when one reviews the remarkable events of chromosome behavior that take place in the intricate details of cell-division, and impressively so in meiosis, it becomes obvious that there is ample opportunity in the life cycle of the chromosomes for interruption of normal chromosome and gene behaviors.

Experimental causes of gene mutation.—It has been found that the X-ray and also radium may be used to break up chromosomes and that their use increases very greatly the occurrences of translocation, duplication, and deficiency of pieces of chromosomes without permanently injuring the cell. Similar changes have been produced by the experimental use of extremes of heat and cold.

The experimental use of the X-ray in genetic research with the fruit fly produces two classes of chromosome disturbance. The first is an "aberrant distribution of pieces of chromosome"[3] resulting in translocation, duplication, and deficiency of chromosome pieces and the gene chains they carry. The second sort of injury affects the single gene, damaging or even destroying it, thus producing a single gene mutation (i.e., change).[4]

Constructive changes in the genes.—We have no convincing evidence that "new" genes are synthetically built by the organs of the nucleus out of protein material in the germ-cell, but such changes, far-fetched as they may now seem to be, are not wholly beyond the range of the possibilities of the physics and chemistry of biology. We do know that injured genes are sometimes reconditioned or restored to their functional competency after a period of ineffectiveness.

Linkage of genes.—Experimental investigations show many records in which certain characters remain associated in succeeding generations of rapidly breeding plants and animals. Pairs of characters remaining together under these circumstances are prod-

[1] C. C. Hurst, *The Mechanism of Creative Evolution* (Macmillan, 1932), pp. 131–32.

[2] Thomas Hunt Morgan, *The Scientific Basis of Evolution,* p. 58.

[3] *Ibid.,* p. 79.

[4] C. C. Hurst, *op. cit.,* p. 189.

ucts of genes that are described as being linked together within the chromosome that carries them.

The "crossing over" of genes.—We have noted that during the prophase preparing for meiosis the spireme formation of the nucleus consists of two chromatin threads, one of maternal and the other of paternal origin, lying side by side. This double spireme phase constitutes the "synaptic" stage[1] in which conjugation of the chromosomes takes place. This is the situation in which it may happen that a short series of linked genes in one chromosome may exchange place with a similar linked series of genes carried by its chromosome mate. This experience between members of the same pair of chromosomes is known as a "crossing over" of genes. It is not a frequent physiological event in the life of the maturing germ-cell. Translocation, duplication, and deficiency are aberrant events, not to be regarded as normal. Crossing over leads to new gene relationships that produce changes in heredity, as shown by the appearance of variations of characteristics and qualities of offspring.

Linkage and crossing over of the genes.—The exchange of genes between members of a pair of chromosomes during conjugation is not an exchange of a single gene between two chromosomes. The transfer is a balanced exchange of a "whole chain of genes" linked together within one chromosome for a similar linked chain from its chromosome mate (see Fig. 16, p. 80).

Segregation of the genes.—We have noted that Mendel's conclusions have been described as his law of segregation of the elements or factors that determine heredity ("Mendel's First Law") and his law of the independent assortment of separate pairs of those elements or factors ("Mendel's Second Law"). We have noted too that Sutton in 1902 called attention to the fact that the behavior of the chromosomes in meiosis accounts for the segregation and independent assortment of the heredity elements or factors carried by the chromosomes. We have called attention to the fact that common practice now designates the heredity elements by the name of "genes." Thus, Mendel's First Law is now known as the "Law of the Segregation of the Genes" and his second as the "Law of the Independent Assortment of the Genes."

We now know that the genes are carried within the chromo-

[1] Edmund B. Wilson, *The Cell in Development and Heredity* (Macmillan, 1925), p. 541.

somes so that the genes of maternal origin are carried in chromosomes of maternal origin and genes of paternal origin are carried within the paternal chromosomes. Thus, in the diploid cell (the somatic-line cell) the genes are always segregated within the chromosomes of mother or father sources that constitute the pairs of chromosomes and pairs of genes that equip the nucleus, a single body-line cell.

But, when the diploid germ-line cell matures and passes through its reduction division (meiosis), the pairs of chromosomes it carries are separated (i.e., a disjunction of the chromosome occurs), one chromosome member of each pair going to one of the new haploid cells produced (a sperm or an ovum) and the other chromosome member going to the other new haploid cell. If the maturing germ-line cell is a hybrid cell, for instance, a germ-line cell produced by the crossing of a pure-line tall pea plant and a pure-line short pea plant, half the total number of mature germ-line cells (unfertilized seeds and pollen) will contain dominant genes for tallness and the other half of the total number of mature haploid germ-line cells will contain recessive genes for shortness. In the process of meiosis, the genes thus remain segregated—the chromosomes carrying recessives from the chromosomes carrying dominants—and carried by the chromosomes that contain them to the nuclei of the mature haploid germ-line cells, the ova and the sperms, that are formed by the reduction division of the maturing male or female germ-line cell.

Segregation of the genes is essential to the orderly normal process of heredity. The two members of each pair of chromosomes (gene carriers), one paternal and one maternal, must separate in order that one member with its gene content may go to one mature germ-line cell and its mate to the other.

Independent assortment of the genes.—During meiosis the chromosomes continue to retain their individual identity. Their functional individuality is determined by the genes they contain. The random assortment of the chromosomes in the metaphase that accompanies meiosis accomplishes an independent reassortment of the genes they carry. Combinations of paired chromosomes in the diploid cell are broken up in segregation, and any of all the mathematically possible chance recombinations may appear in the ovum or sperm. Thus the hybrid combination of genes that determined certain characters and qualities of one or both parents

is broken up (disjoined) when the diploid germ-line cells mature and by their reduction divisions (meiosis) produce haploid germ-line cells. The genes are thus reassorted in the haploid chromosome groups, independently of their preceding hybrid assortment in the parental diploid chromosome groups, regardless of the number of hybrid characteristics present in the parent or parents.

Behavior of the genes in meiosis.—During the interphase (the "resting stage" of mitosis or preceding meiosis) the genes are probably located in the reticulum of the nucleus, the reticulum being the structural form taken by the chromatin material during this phase of the chromosome cycle.

The formation of the spireme during the prophase places the genes in the long thin threads of the spireme in a series that, as we have noted before, may be likened to a series of zones, each zone being a gene. When the spireme thread of maternal origin lies side by side with the spireme thread of paternal origin, the pair of threads are composed of pairs of genes, so that genes of paternal origin lie side by side with similar genes of maternal origin. Thus, for example, the paternal genes that determine the characteristic of tallness or shortness in one thread lie side by side with maternal genes for tallness or shortness in the other thread.

As the prophase develops, the chromatin threads (i.e., the spireme threads) thicken and segment so that the individual chromosomes characteristic of the sort of animal or plant they assist in producing may be seen and recognized individually and in their characteristic number through the microscope. (In some sorts of plants and animals the chromosomes never lose completely their microscopic visibility.) The period of time in which the maternal spireme thread with its chain of chromosomes and their content of genes lies by the side of the paternal spireme with a chromosome mate for every chromosome in the maternal chain of chromosomes, and with a gene mate for every gene in the maternal chain of genes, is called, as we have noted above, the stage of synapsis or the stage of conjugation of the chromosomes. This is the stage in which the genes from one chromosome may cross over and change places with similar genes from its companion chromosome (its chromosome mate) lying at its side.

Thus during the prophase the genes are found in their native paternal and maternal chromosome zones, each gene occupying its own place in the chain of genes to which it belongs, regardless of

what may have happened to it during the preceding metaphase. The genes of paternal origin are thus segregated within the paternal chromosomes and the genes of maternal origin are segregated in the chromosomes of maternal origin. It may be that this segregation of the genes is not disturbed during the preceding interphase and that the nuclear reticulum of the so-called "resting stage" does not lose its regional paternal and maternal identity. In any event, the fact of the segregation of the genes becomes impressively obvious by virtue of our precise knowledge of the events that take place in the prophase leading to meiosis. The prophase thus furnishes the living "mechanism" for the operation of Mendel's First Law—the Law of the Segregation of the Genes.

The metaphase brings the chromosome pairs to the equatorial plane (or plate) of the cell. We note again that each pair of chromosomes consists of a chromosome of maternal origin and a chromosome of paternal origin. The genes in a chromosome of maternal (or paternal) origin may include a short chain of genes that has been received in exchange for a similar short chain that has crossed over to the paternal (or maternal) chromosome mate during conjugation. Otherwise, and this is probably most often the case, all the genes of a given chromosome have the same sex origin, the paternal chromosomes containing only genes of paternal origin and the maternal chromosomes containing only genes of maternal origin.

The metaphase in meiosis accomplishes an essential part of one of the most mysterious and awe-inspiring processes in all nature. This is the achievement that finally places the chromosome pairs in the equatorial plane of the cell in a random assortment so that it is a matter of chance which member of a given pair of chromosomes (i.e., the paternal member or the maternal member) faces one pole or the other pole of the cell. In this process each chromosome pair behaves independently of all other chromosome pairs, so that there is necessarily an independent assortment of the genes carried by the chromosomes, thus furnishing the living mechanism of Mendel's Second Law—the Law of the Independent Assortment of the Genes.

The anaphase in meiosis is the stage in which all the chromosomes (brought to the equatorial plane in the metaphase) facing one pole of the cell migrate toward that pole and all those facing the other pole migrate to the other pole. Thus, half the chromo-

somes that appeared in the prophase now migrate to one pole and the other half migrate to the opposite pole. For each chromosome at one pole there is a mate at the opposite pole. For each gene at one pole there is a mate at the other pole.

The assortment of the chromosomes in the phases of meiosis is not only an independent assortment regardless of preceding hybrid physiological associations between the genes (i.e., the factors that determine heredity) of one chromosome and their gene mates in the homologous chromosome, but in the metaphase it is also a random assortment of all the chromosome pairs (one member a chromosome of maternal origin and the other a chromosome of paternal origin) in which the law of chance offers opportunity for all the variations in the sequence of polar facings that are mathematically possible with the total number of paternal-maternal pairs of chromosomes present. The human diploid germ-line cell contains twenty-four pairs of chromosomes. The random assortment of these twenty-four pairs in a single metaphase in meiosis may produce any one of the 16,777,216[1] combinations of chromosomes to which we have referred on earlier pages.

But it is here that the "aberrant distribution of pieces of chromosomes," and therefore of chains of genes, may take place. The migration of a chromosome may be accompanied by dragging a piece of its chromosome mate, or a piece of a chromosome not its mate, along with it, the chromosome that lost a piece of itself migrating to the opposite pole. This aberrant distribution, as noted above, may lead to translocation, duplication, or deficiency of genes (and even of chromosomes). The effects of these aberrant distributions of pieces of chromosomes and their gene content are reported as causes of serious damage and even death of the offspring produced—chiefly the offspring of *Drosophila*.

Thus each of the two "new" cells completed by the telophase in meiosis contains half the total number of chromosomes and genes that were assorted at random at the completion of the prophase. One of these "new" cells contains all the chromosomes and genes that migrated to one pole during the anaphase, and the other "new" cell contains all the chromosomes and genes that migrated to the other pole. The chromosomes and the genes they

[1] Edwin Grant Conklin, *Heredity and Environment in the Development of Men* (Princeton University Press, 1923), p. 174.

contain are no longer in pairs. Each cell contains a single thread of chromosomes with its strings of gene disks or zones. The chromosome and gene mates have been separated and distributed to the new cells so that each chromosome in one of the two cells has a chromosome mate in the other and each gene in a chromosome in one cell has a gene mate in the homologous chromosome in the other cell, excepting, of course, in the sex-chromosomes. Thus, the two new cells produced by meiosis are haploid cells, not only in chromosome number but also in the number of genes they contain.

The telophase in meiosis is the state in which the cell as a whole completes its division into two new cells (daughter-cells) each containing one-half the species number of chromosomes (the haploid number). The nucleus of each of these two daughter-cells contains one complete set of chromosomes, and each set of chromosomes contains one complete set of genes. The word "complete" here refers to the haploid number of chromosomes and genes characteristic of a given sort (species) of plant or animal.

Simultaneously with this reduction division (meiosis), or immediately thereafter, the two new haploid cells divide, so that four haploid cells are produced, each completely equipped with the chromosomes and the genes of its species. This second division is typical of the division that occurs in mitosis. Each chromosome splits longitudinally into two chromosomes that are identical quantitatively and qualitatively. The splitting of the chromosomes is also a splitting of the genes within the chromosomes. So that for each gene there are produced two "new" genes precisely alike, quantitatively and qualitatively.

It is immaterial when these two divisions take place, simultaneously or otherwise. The important fact is that they lead, in the male germ-line cells, to the production of four mature sperm-cells each carrying a haploid number of chromosomes and genes, and in the female germ-line cell to the production of one mature ovum and three abortive ova. All four of these ova contain the haploid number of chromosomes and genes, but the three that die and disappear have little or no cytoplasm. What other deficiencies the three may have are not important to our discussion.

Behavior of the genes in fertilization.—We have noted that the union of a sperm and an ovum in fertilization brings two haploid germ-line cells together forming a single diploid germ-line

cell—the fertilized ovum—that contains two complete sets of chromosomes and genes. The normal heritage of a fertilized ovum thus brings it two sets of heredity factors that under the influence of favorable experience with favorable environment determine its growth and development into an individual with the characteristics of his species. But this normal heritage of the fertilized ovum is equipped for the determination and regulation not only of hereditary similarities that identify species or families, but also of hereditary differences or variations that with the assistance of environmental influences distinguish individuals from each other despite their fundamental hereditary similarities.

We have noted that there are 16,777,216 different combinations of chromosomes (gene containers) possible in the random assortment that leads to the production of a sperm or of an ovum having one of that enormous number of combinations for the inheritance of individual differences. The union of sperm and ovum in fertilization, as Conklin states, increases the range of chance combination to "approximately three hundred thousand billion" chances in the lottery of individual hereditary differences.

The behavior of the chromosomes and genes in fertilization accounts for the Mendelian ratios in which children are born. When the fertilization is between genes of pure-line heredity for a given character or quality, all of the offspring display the same pure-line heredity. If the fertilization is between dominant genes for a given characteristic or quality and recessive genes for the contrasting characteristic or quality, all the children will display the dominant heredity but they will be hybrid children so far as that particular heredity is concerned. When the fertilization is a chance union between ova from a parent who is hybrid for a given pair of contrasting characteristics or qualities and sperms from a parent of similar hybrid characteristics or qualities, the children will display their consequent heritages in the ratio of one pure-line dominant to two hybrid dominant to one recessive.

Behavior of genes in mitosis.—The fertilized ovum divides by mitosis into two "daughter-cells"; these two into four; and so on until in mankind something like four thousand billion tissue cells (chiefly somatic-line cells) are produced.

The dividing cell in this process passes through the stages of (1) interphase, (2) prophase, (3) metaphase, and (4) telophase. In all these phases the genes, under normal conditions, retain their

chromosome relationships. When the chromosomes are split longitudinally in the metaphase, the genes they contain are split so that the two "new" chromosomes contain "new" genes, one of the new pair of chromosomes being precisely like the other in size, shape, and function; and necessarily every gene in one of the "new" chromosomes is precisely like its mate in the same gene zone in the other chromosome. Every normal living cell of the human body thus contains a complete set of chromosomes and a complete set of genes.

Behavior of the genes of the human sex-chromosomes.—Sex is a Mendelian character.[1] It is inherited. The determination of sex is apparently not the influence of a single gene (i.e., a single heredity factor) but rather the integrating influence of a number of genes in the X-chromosomes of the germ-line cells. We have noted on preceding pages that, in the presence of two X-chromosomes in the fertilized ovum, a female develops; if there is only one X-chromosome, the fertilized ovum develops into a male. Thus, as a result of meiosis, every ovum produced contains an X-chromosome carrying genes that determine sex; one half the sperms produced contain no genes concerned with the determination of sex; every sperm in the other half contains one X-chromosome carrying sex-determining genes. The union in fertilization of a sperm and an ovum both of which carry such genes determines the development of a female. The union of an ovum containing such chromosome and genes with a sperm that has no such chromosome and genes (a Y-chromosome) determines the development of a male.

Recessive genes present in one X-chromosome would participate in the determination of hereditary characters when that chromosome is without a chromosome mate in fertilization. Under these circumstances the male offspring would inherit the sex-linked heredity determined by the recessive genes carried in the maternal X-chromosome. Recessive genes in the X-chromosome of a sperm united in fertilization with similar recessive genes in the X-chromosome of an ovum would determine the inheritance of the recessive character by the female offspring.

The genes of the sex-chromosomes behave in accord with the principles announced by Mendel.

[1] Edwin Grant Conklin, *Heredity and Environment in the Development of Men,* sixth edition (Princeton University Press, 1930), p. 166.

Genes in heritage.—The growth, development, and differentiation of an individual from his status as a single microscopic protoplasmic cell to his structural and functional completion as an organism composed of some thousands of billions of cells is a product of interactions between his heritage and his environment. His heritage, with which his life begins, is a combination of a living sperm and a living egg, each containing its contribution of cytoplasm and nucleoplasm equipped with their essential living integrating organs. In our discussion of these organs of the cell, we have noted the essential part played by the genes in relation to the determination of the hereditary characters and qualities that will distinguish the individual produced physically, mentally, and socially under the influence of his growth and development. We have called attention to the fact that because of repeated mitosis his heritage of genes will furnish a full equipment of genes in every living protoplasmic cell of which he is constructed. We have noted too that the individual is constructed of somatic-line cells and germ-line cells, and that the somatic-line cells through their growth in numbers and size and shape and through their structural and functional specialization constitute the individual, structurally and functionally, i.e., physically, mentally, and socially. Thus, it appears that a heritage of somatic-cell genes plays a determining part in the miracle of creating a new individual, building him like others of his kind, and, at the same time, giving him a form, a mind, and a personality that distinguish him from every other individual. The part played by the genes in this miracle of all miracles is a part of a whole in which other known and unknown influences are present and essential. These other influences are furnished by other organs of the cell, by the environment of the cell, and by the activities of the whole cell in relation to its environment.

Genes as factors in the determination of health.—The conclusions already stated on preceding pages are of such importance as to justify their restatement, summarizing the fact that, as essential parts of an essential biological whole, the somatic-line genes participate in furnishing a favorable health heritage (and sometimes an unfavorable health heritage) to every tissue cell and every organ of the human body, and, therefore, to every somatic, mental, and social functional possibility of the whole individual.

Custodial care of genes.—We have noted elsewhere the fact

that the individual is custodian of the heredity factors he receives from his parents and transmits to his children. These factors, the germ-cell genes, are carried in the chromosomes of the gonad cells of the testes of the male and in the gonad cells of the ovaries of the female. This custodial relationship brings a responsibility that justifies a serious consideration of the possibility of improving the genes in one's custody, protecting them from injury, and making sure that they are united with genes of sound health when joined in fertilization with those of a mate. The details of such planning belong to the practice of individual hygiene, group hygiene (the family group), and societal hygiene. But the principles that determine the limitations and possibilities of the practice of hygiene belong to our consideration here. These principles as related to the hygiene of heredity are set forth in this chapter. They establish the fact that there is no way at our disposal that would enable us to get rid of an undesirable equipment of genes in germ-line cells. We know of no way in which to "improve" a gene. We cannot construct a new gene.

We know that the life and health of a protoplasmic cell, whether it be a germ-line cell or some other sort of cell, depends on favorable temperature and adequate respiratory oxygen, water, food (protein, carbohydrate, and fat), inorganic salts, vitamins, and perhaps other as yet unknown environmental factors. Every organ of a cell depends on the health and life of the cell of which it is a part for its own health and life. It follows that the maintenance of the life and health of germ-cell genes depends on the favorable adequacy of the factors noted above. These requirements of the protoplasmic cell constitute principles that determine the practice of hygiene by the individual, by the family, and by society. Our responsibility for the custodial care of the genes in our germ-line cells is a responsibility that we are forced to satisfy more or less adequately so far as their needs for warmth, water, oxygen, food, inorganic salts, and vitamins are concerned. Food hunger, air "hunger," and thirst compel us to eat, breathe, and drink. Thus, within limitations, we maintain autonomically the life and health of our germ-line cells and the genes they contain.

We have some information concerning agents that may injure the chromosomes of germ-line cells and the genes they contain. Such agents are the X-ray and radium emanations, certain chemicals in solution, extremes of heat and cold, and the poisons of cer-

tain diseases. Obviously the application of such agents to damage of human germ-cells and their chromosome and gene contents is limited and unusual. Nevertheless, a calculated intelligent program of living should take into account such hazards as these.

Finally, the principles of heredity that we are discussing establish the fact that our custodial care of germ-cell genes places a responsibility on the individual, on the family, and on society for the prevention of gene unions in parental matings that start new lives doomed from their beginnings to deficiency, defect, or disaster—physically, mentally, or socially.

CHAPTER VIII

CYTOLOGICAL ORIGIN OF THE PRINCIPLES THAT DETERMINE THE HYGIENE OF HEREDITY (CONCLUDED)

Heredity influence of regional differences in the nucleus. In addition to the organs of the nucleus that we have described as the living machineries that enforce the Mendelian principles (unit characters, dominance, and segregation) and their modifications and extensions,[1] there may be other nuclear constituents of importance in their influence on heredity and on growth and development. There may be other self-perpetuating factors present. These other living parts of the nucleus, if they exist, have regional locations in the nucleus so that they would have an unequal distribution to the nuclei of the new cells that are formed by mitosis. Such an unequal distribution would result in a differentiation of influences on the hereditary characteristics and qualities developed through one series of somatic-line cells as compared with other series of cells.

The cytoplasm in heredity.—A fertilized ovum with which a human life begins is a union of a sperm-cell having very little cytoplasm and an egg-cell having relatively a very large amount of cytoplasm.[2] Each of these mature germ-cells furnishes an equal amount of germ plasm—equal as to number of chromosomes and genes. But their cytoplasmic contributions are most unequal quantitatively and qualitatively.

Our amazement at the orderly behavior of the chromosomes and genes and our almost awesome interest in searching the determining parts they play in heredity easily lead us to overlook the behaviors and functions of other living parts of the nucleus and to neglect the living structural organization and functions of the cytoplasm. We are fascinated by the orderly precision of mitosis, the segregation of the genes, conjugation of the chromosomes and the crossing over of genes, the independent assortment of the genes, the random assortment and distribution of the chromo-

[1] See Edwin Grant Conklin, *Heredity and Environment in the Development of Men* (Princeton University Press, 1930), p. 99, "Summary of Mendelian Principles," and p. 100, "Modification and Extension of Mendelian Principles."

[2] See Edwin Grant Conklin, *Heredity and Environment in the Development of Men* (Princeton University Press, 1923), p. 196; and Thomas Hunt Morgan, *The Scientific Basis of Evolution* (W. W. Norton & Company, 1932), p. 45.

somes, the reduction division of diploid germ-line cells to haploid sperms and ova, the restoration of the diploid number in fertilization, the "mechanistic" behavior of the chromosomes in fertilization that accounts for the Mendelian ratios, and the exact qualitative and quantitative halving of the chromosomes and genes in cell-division. But the important fact remains that cell-division is a phenomenon of the whole cell, including the whole cytoplasm as well as the whole nucleus.

Cytoplasmic regional differences and their significance.—The cytoplasm of the fertilized ovum is not a homogeneous undifferentiated substance. It is an organization of different living structures. They differ from each other structurally and functionally. They are not located symmetrically in the cell. Such a living structure may be called a cytoplasmic organ or a group of organs of the cytoplasm, each organ having a special function—or variety of functions—of its own, but all of them utterly dependent upon each other.

We know that the egg-cell even before fertilization has a structural and functional organization that determines its fore end, hind end, and bilateral symmetry, and the dorsal and ventral surfaces of the embryo into which it finally develops.

The cleavage of the fertilized ovum producing the two "new" cells with which the embryo begins its existence divides the cytoplasm of the fertilized ovum into two parts. These two cytoplasmic parts may be quantitatively equal but are not necessarily so. They cannot be qualitatively equal. The cytoplasm of one of these two new cells must be different in certain of its living constituent regional parts from the living parts of the cytoplasm of the other new cell.

Later cleavages of the embryonic cells are known to produce obvious unequal quantitative and qualitative divisions of the cytoplasms of the "new" cells that are formed. The cleavages of the human fertilized ovum and its cell progeny provide the growing, developing embryo with a complete set of embryonic tissue cells. We note again that (1) the nucleus of every one of these varied sorts of specialized cells contains two sets of chromosomes and genes; (2) one set is of maternal origin, the other of paternal origin; (3) every tissue cell thus contains two complete sets of chromosomes, twenty-four in each set; the twenty-four pairs in one cell are precisely like the twenty-four pairs in every other cell of

the embryo; the string of genes of a single chromosome is precisely the same, gene for gene, as the string of genes in that chromosome in all the other cells; the string of genes of a single chromosome is similar, gene for gene, to its homologous chromosomes in all other cells. Thus there is a qualitative similarity of chromosomes and genes in the nuclei of all the cells of the embryo. There are quantitative chromosomal differences. For instance, the chromosomes of the salivary glands of *Drosophila* are immensely larger than those of the egg and sperm whence they came.

There may be differences in the other constituents of the nucleoplasm transmitted by cell-division from cells to their daughter-cells, but the chromosome and gene content of all the cells of an embryo are the same.

But cell-division produces differences in the cytoplasms of "new" cells with the same inexorable certainty as it produces identical chromosome sets and gene chains. The process of mitosis, accompanied by cleavages of cells at different planes, thus leads to the formation of an embryo made up of cells that because of interactions between their common chromosomes and genes and their differentiated cytoplasms will develop and specialize into muscle tissue cells; cells that will develop into nerve tissue cells; others that will develop into gland tissue cells; others, into bone tissue cells, connective tissue cells, fat tissue cells, and every other sort of special cell with which a normal human body is equipped for the purpose of living and achieving and maintaining physical, mental, and social health.

Interaction between nucleus and cytoplasm.—This process of growth from a single fertilized ovum into a multicellular organism and the inseparable process of development from the functions of a single fertilized ovum to the specialized tissue-cell functions of the whole organism—the whole being essential to the maintenance of its life and health—are products of interactions between the organs of the nucleus of the cell and the organs of the cytoplasm of the cell. Our present knowledge leads us to state that the chromosome-gene content is the same in all cells of the individual; that the regional organization of the cytoplasm of the cells of the individual differs from his very beginning as a single fertilized ovum; and that the interactions between the nuclei (each nucleus having a content of chromosome-gene material common to all his cells) and different cytoplasmic organs in differ-

ent generations of embryonic cells lead to the development and specialization of tissue cells and, along with other environmental influences, to the formation of the organs, organ systems, and the total structure, shape, and functions of the whole individual.

Share of chromosomes and cytoplasm in heredity and development.—"It will be observed that the correlation between chromosomes and adult characters is different in kind from that between cytoplasm of the egg and adult characters; in the latter case, polarity, symmetry, and pattern of location are characters of the same kind in the egg and in the adult and the correspondence is comparatively close; in the former there is no correspondence in *kind* between the chromosomal peculiarities and the peculiarities of the adult. This fact suggests that the chromosomal organization is more fundamental than that of the cytoplasm; the chromosomes contain the germ plasm; the cytoplasm is the somatoplasm; the chromosomes are chiefly concerned in heredity, the cytoplasm in development."[1]

Summary of the influence of the study of the cell (cytology) upon our knowledge of the principles of heredity.—The careful work of many prepared investigators in all parts of the world involving the examination and experimental investigation of the cells of an enormous number of individual plants and animals and of an enormous number of different sorts of plants and animals has given mankind a proved, precise knowledge of the essential parts played by the cell in heredity and development. Gregor Mendel, De Vries, Tschermak, and their followers gave us knowledge of certain fundamental principles of heredity based on their remarkable experimental investigations of the hybridization of plants. Experimental hybridization with animals has verified the Mendelian principles for animals as well as for plants. We know that those principles apply with equal validity to human heredity. The products of cytological research have demonstrated the cellular behaviors that produce the Mendelian phenomena of dominance and recessiveness, segregation and independent assortment of the factors that determine heredity (i.e., the genes), the Mendelian ratios, and blending.

The study of the cell has brought us a knowledge of the be-

[1] Edwin Grant Conklin, *Heredity and Environment in the Development of Men* (Princeton University Press, 1930), p. 207.

haviors of the chromosomes and genes in heredity that has given genetics[1] the precision of an exact science. The principles of heredity have been established by empirical observation, statistical comparisons, experimental hybridization, and cytological research. Expansion of our knowledge and perhaps the addition of new principles of heredity now unrecognized are the promises of current genetic research along all these lines.

[1] "Genetics may be defined as the science which deals with the *coming into being* of organisms . . . . the present every-day creation of new individuals or new races . . . . the part that parent organisms have in bringing new organisms into being . . . . the influences which parents exert on the characteristics of their offspring . . . . nearly equivalent to heredity . . . . concerned with all agencies which . . . . affect, condition or limit the coming into being of a new organism or a new race. All physical and chemical changes in the world outside the organism, or in a word the environment, vitally concern genetics, though they are the more immediate field of study of other branches of biology."—W. E. Castle, *Genetics and Eugenics* (Harvard University Press, 1930), Introduction, p. 3.

CHAPTER IX

THE PRINCIPLES OF HEREDITY THAT ARE PRINCIPLES OF HYGIENE

The study of heredity that we have described has furnished a knowledge of principles of hygiene that are essential to the ultimate determination and regulation of the production, improvement, maintenance, and defense of health—physical, mental, and social health. These principles of the hygiene of heredity may be stated as follows:

1. The child, youth, or potent adult is a custodian of factors (the genes within his germ-line cell chromosomes) that determine heredity. As custodian, the individual has a responsibility for the heredity that he with a mate may transmit to their children.

2. These factors (genes) are contained in the chromosomes of the germ-line cells in the gonad glands of the ovaries of the female and in the gonad glands of the testes of the male.

3. The chromosomes and genes of the germ-line cells are subject to the possibility of injury from chemicals in solution brought to them in the blood stream (blood capillaries and lymph spaces) that bathes them and upon which the germ-line cells in common with all other protoplasmic cells depend for the satisfaction of their essential requirements for optimal temperature, water, respiratory oxygen, food, inorganic salts, vitamins, and perhaps other as yet unknown essential factors. The chemical injury or destruction of genes within the chromosome would serve as a source of damage to offspring that might be produced.

4. Laboratory experiments prove that chromosomes are disturbed and even broken up into fragments and genes damaged or even destroyed by the action not only of adverse chemical influences but also of extremes of temperature, starvation, application of X-ray or radium emanations. It is not without the range of possibility that such disturbing or damaging influences might reach the germ-line cells or the mature sperms or ova of the individual custodian and become the sources of damaged or lethal hereditary factors.

5. There is proof that exceedingly minute pathogenic organisms[1] sometimes enter the ova of silkworms, certain ticks, and

[1] A pathogenic organism is an organism that causes disease, such as the diphtheria bacillus, the spirochete of syphilis, and the bacillus of tuberculosis.

other lower animals and birds, so that the diseases caused by those pathogens are transmitted through fertilization.[1] The organism that causes Rocky Mountain spotted fever is transmitted in the ova of certain ticks.[2] Under such circumstances the ova serve as carriers of disease organisms, but the organisms themselves cannot be said to be a part of the living heredity process. They are foreign bodies in and not living parts of the ova.

6. So far as we know, there is no possibility within the range of human influence of adding a "new" gene or of reconditioning an old one for the betterment of heredity.

7. Acquired characteristics or qualities are not transmitted from parent to children. It is not possible for one to acquire characteristics or qualities that would improve the transmissible factors (genes) of which he is custodian nor to add a transmissible factor (gene) to those of which he is already custodian.

8. The vast majority of factors that determine heredity are factors favorable to normal life and health of offspring. A favorable health heritage in the presence of favorable environment and under the influence of favorable experience with that environment determines the production, maintenance, and defense of physical, mental, and social life and health. The individual cannot improve his heritage, but he can by himself (through individual hygiene) and with the aid of others (group and societal hygiene) improve and control his environment (physical, biological, and social environment), making it favorable to his health requirements (physical, mental, and social). He can lead an active "whole" life in relation to that environment, satisfying thereby the basic requirements of his constituent tissue cells for optimal range of temperature, respiratory oxygen, water, food, inorganic salts, and vitamins. He can satisfy also the biological law of use through which he may educate himself physically, mentally, and socially up toward the limit of his heritage of possibilities and thus build toward his individual somatic, mental, and social health possibilities.

9. Matings between parents who are custodians of pure-line heredities favorable to health produce children of pure-line health

[1] Theobald Smith, *Parasitism and Disease* (Princeton University Press, 1934), p. 132.

[2] See Hans Zinsser, *Rats, Lice, and History* (Little, Brown & Company, 1935), chap. xi.

heritage who in turn are custodians of pure-line health heredities which they may contribute, with the aid of a mate, to their children.

10. Matings between parents who are custodians of pure-line heredities that determine health defects or deficiencies or disease produce children of pure-line heritage of such defects, deficiencies, or disease who will all be custodians of pure-line heredities (custodians of chromosomes that contain genes that determine such heredities) similarly unfavorable to the health heritage of the children they may assist in producing.

11. Dominant heredities (dominant genes) are with few exceptions causes of favorable health heritage—that is to say, of heritage that, under the influence of favorable experience with favorable environment, produce, maintain, and defend health—physical, mental, and social. There are some dominant heredities that determine the heritage of disease. Fortunately, they are few in number.

12. Unfavorable health heritages are due usually to recessive heredity factors (recessive genes) furnished by both mates. A recessive heredity unfavorable to health furnished by one mate, the other contributing a dominant heredity for the contrasting normal health characteristic or quality, is not evident in the heritage of the children produced. Such combinations of dominant heredity factors for health with recessive factors for contrasting health defects or deficiencies produce children who are hybrids for the contrasting health characteristics or qualities. All these children will show a favorable health heritage determined by the dominant factor, in accord with Mendelian principles. All the children of such matings will be custodians of the recessive heredity factors transmitted by the one parent and also the dominant normal contrasting factors furnished by the other parent.

13. Matings between parents both of whom carry one set of chromosomes containing dominant genes for a given health characteristic or quality and one set of chromosomes containing recessive genes for the contrasting health defect or deficiency would produce children, if a sufficient number were born, in accord with the Mendelian ratios. There would be one child of dominant pure-line favorable health heritage, to two children of normal favorable but hybrid health heritage, to one child with pure-line recessive unfavorable health heritage.

14. Differences in the total composite health heritages that, under the influence of their favorable experience with their favorable environment, produce men and women of varied individual differences in their hereditary characteristics and qualities of health are almost infinite in number. This is true because of the operation of the law of chance that governs:

a) The random assortment and distribution of the maternal-paternal pairs of chromosomes in meiosis, that make possible as many as 16,777,216 different combinations of chromosomes in the different mature germ-line cells produced by a single individual.

b) The enormous number of sperm-cells produced by the gonad glands of the testes in the life of an individual man. "It is estimated that at ejaculation each cubic centimeter of the liquid contains from sixty to seventy million of these cells."[1]

c) The large number of ova produced by the gonad glands of the ovaries during the life of an individual woman. This number is variously reported. The ovaries of a newly born child may contain as many as eight hundred thousand immature ova. During the mature life of the woman, between adolescence and the climacteric, as many as two thousand may mature. Of this number very few will participate in fertilization.

d) The chance union of one ovum and one sperm in fertilization. ". . . . and the possible number of different combinations of fertilized eggs or oösperms which could be produced by a single pair of parents would be $(16{,}777{,}216)^2$, or approximately three hundred thousand billion."[2]

e) "But probably other things than chromosomes differ in different germ cells, and it is by no means certain that individual chromosomes are always composed of the same chromomeres, or units of the next smaller order, and in view of these possibilities it may well be that every human germ cell differs morphologically and physiologically from every other one, in short that every oösperm and every individual which develops from it is absolutely unique."[3]

[1] William H. Howell, *A Text Book of Physiology* (W. B. Saunders, 1933), p. 1071.

[2] Edwin Grant Conklin, *Heredity and Environment in the Development of Men* (Princeton University Press, 1923), p. 174.

[3] *Ibid.*

f) The small number of children produced in a single human family.

g) Also, changes in the gene content of chromosomes that occur because of the crossing over of the genes during conjugation preparatory to meiosis; and changes due to the aberrant distribution of chromosome pieces that may be broken off in the transition from the metaphase to the anaphase in meiosis (see item *e* above).

CHAPTER X

A BRIEF PREVIEW OF THE PRACTICE OF THE HYGIENE OF HEREDITY

The practice contrasted with the principles of the hygiene of heredity.—In preceding chapters on the hygiene of heredity we have discussed the causes—the sequences of cause and effect—that determine and regulate the production, improvement, maintenance, and defense of heredities favorable to health. Those causes constitute the principles of the hygiene of heredity. The practices of the hygiene of heredity are the behaviors of organisms or species (plants or animals) that execute (i.e., carry out) those principles. The practices of the hygiene of heredity by mankind are behaviors of the individual, the family and other groups, and of society. The behaviors of lower organisms are autonomic behaviors. They are forced practices. Voluntary, calculated attempts to influence heredity for the betterment of physical, mental, and social health are possible and are made, so far as we know, only by mankind. These attempts constitute the programs of eugenics.

Thus the practice of the hygiene of heredity is autonomic. Among human beings it may also be voluntaristic, to an important extent at least.

Autonomic practice of the hygiene of heredity.—After fertilization takes place, the ensuing behaviors of the living fertilized ovum and its progeny of somatic-line and germ-line cells execute the processes of heredity autonomically, beyond the reach of voluntaristic control. The behavior of every cell is determined autonomically by its content of inherited dynamic genes, its integrating cytoplasm, and its essential environment. The government of cell behavior in heredity is beyond the direct reach of the voluntary mind of which it is a part. Mitosis, variation in cleavage planes, hereditary growth and development, maturation of germ-line cells, segregation and independent assortment of genes, crossing over, random assortment, and distribution of chromosomes in the metaphase and anaphase of meiosis, the chance union of sperm and ovum—all these are factors that make up the total composite of behavior that constitutes the autonomic practices of the hygiene of heredity.

The living processes that take place in the human chromosome

cycle—the mitosis, meiosis, and fertilization of germ-line cells and the mitosis of somatic-line cells—are beyond the direct reach of our planned control. We cannot add a gene nor take one away. We cannot select the assortment of chromosomes we prefer for the health heritage with which we would endow our children. Fortunately, normal health heredities are far more frequently dominant than recessive. The processes of meiosis and fertilization, autonomic though they may be, are far more likely to transmit favorable health heredities than those that are unfavorable. Unfortunately, the autonomic assortments and distributions of chromosomes carrying recessive genes unfavorable to health do participate in fertilizations that produce heritages unfavorable to health.

Voluntaristic, constructive hygiene of heredity.—Much calculating, successful work has been done for the production of desired "improvements" in the breeds of vegetables, fruits, grains, flowers, and other plants, and of cattle, sheep, horses, pigs, dogs, cats, and other animals; but experimental research with human heredity and the calculated application of our knowledge of the principles of heredity for the improvement of human breeds is extremely difficult.

The voluntaristic production, improvement, maintenance, or defense of heredities that are favorable to human health are problems that involve a planned, managed solution set up by the individual, by the family, and by society. They are therefore problems that belong to the practice of individual hygiene, group hygiene, and societal hygiene. These problems are related to our later texts on the practice of hygiene rather than to this one on principles. Nevertheless, it is important to take here a brief preview of the applications of the principles of heredity to the practice of hygiene.

Practices of hygiene for the improvement, maintenance, and defense of heredity:

1. *By the individual.*—The possibility of setting up a planned life by and for the individual that will enable him to influence the heredities of which he is custodian is limited, first, to the maintenance and protection of his germ-line cells; and, second, to the choice of a mate whose germ-line cells, in union with his own, will combine in fertilization to furnish a heritage favorable to the health of their children. One maintains and protects his germ-line cells by furnishing them with a favorable environment of circulat-

ing blood and lymph. If he leads a wholesome, normal life, balanced in its program of nutrition, work, rest, play, and sleep, and safeguarded against the agents that injure health, he will be doing all that he can do voluntaristically to furnish his constituent protoplasmic cells, his germ-line cells included (gonad-gland cells of the ovaries or of the testes), with the requisite optimal temperature, respiratory oxygen, tissue fluid, balanced food rations, mineral salts, hormones, and vitamins essential to the maintenance of their protoplasmic health. His germ-line cells will not be subjected to injury from excessive X-ray or radium emanations, chemical poisons circulating in his blood stream, the invasion of pathogenic organisms, or the toxins of infectious diseases such as syphilis.

2. *By the family.*—The family, built as it must be around a husband and wife, is the most important health unit of society. One of the most significant problems in human life is present—though usually unrecognized—when men and women contemplate matrimony. This problem has to do with the decision as to the sort of heritage their children would receive because of the joint heredities that the two mates would transmit. There is no absolutely certain way by which one can make sure of the heredities in his own custody nor of those in the custody of his mate.

We are all hybrids for many contrasting characters and we all carry hidden recessives that, if combined in fertilization with similar recessives, produce heredities unfavorable to health. Fortunately, as has been noted in earlier paragraphs, dominants that determine favorable health heritages predominate so that the chances of our children receiving favorable health heritage are far greater than the chances that the gift of life they receive from us will be a damaged heritage of poor bodily, mental, or social health.

Too many marriages take place with no forethought as to the effect of obvious undesirable heredities of the parents upon the children that are to come. Thought should be given in favor of the union of sound health heredities and the discontinuance of heredities unfavorable to health, even as such thought was given by Lycurgus and Plato many centuries ago. The young man and the young woman contemplating matrimony, parenthood, and home building—the most important, privileged relations of human life—should seek the competent advice of a trusted health coun-

selor with reference to the whole problem of safeguarded, healthful mating, with special reference to the favor and hazard of the probable heredity combinations involved.

3. *By society.*—The beginnings of the practices of society for the preservation of good human heredities and the termination of bad human breeds occurred many centuries ago. We have noted on an earlier page that the Spartans under Lycurgus had even then a well-defined plan for such purposes.

Our modern societal practice for the betterment of human heredity has been known by the title of "eugenics" since, as we have already noted, its introduction by Francis Galton in 1865.

The efforts of society to maintain sound racial stock and to improve racial stock belong to what has been called "positive or constructive eugenics." Societal efforts to prevent unfavorable health heritages may be called "defensive eugenics." Constructive eugenics involves measures for the encouragement of the combination and reproduction of the best heredities. They include (*a*) proved information concerning heredity, (*b*) selective mating, and (*c*) combinations and reproductions of superior heredities. Defensive eugenics involves efforts to control the mating and prevent the reproduction of unfit heredities. The known menaces to racial stock—mating of the unfit, excessive birth rate of the unfit, war, unwise charity, undesirable immigration, and low birth rate of superior strains—classify the negative and restrictive measures of defensive eugenics, to wit (*a*) segregation or sterilization of the unfit, (*b*) prevention of war, (*c*) intelligent management of charity, and (*d*) prevention of the immigration of the unfit.

CHAPTER XI

SUMMARY OF HUMAN APPLICATIONS OF THE PRINCIPLES THAT DETERMINE THE IMPROVEMENT, MAINTENANCE, AND DEFENSE OF HEREDITY

It has been shown that the development of the single fertilized ovum into a living human child is a process of enormous cell-multiplication and of marvelous cell-specialization. From the union of the two parental cells into the single fertilized egg-cell there come into being an infinite number of individual cells, and these are specialized into a number of types of cells for the accomplishment of the various life purposes of the human body. They are specialized into bone-cells, muscle-cells, gland-cells, nerve-cells, special sense cells (visual, auditory, taste, smell), brain-cells, and so on. And the single fertilized ovum produces not only these complicated differentiated developments into specialized body-cells for the ordinary life-purposes of the individual but also, by its own multiplication, the germ-cell tissues which in due time produce germ-cells and give the individual the possibility of parenthood. The two germ-cells that formed the fertilized ovum gave it the power of self-perpetuation! And so every human germ-cell comes from a pre-existing human germ-cell. This is a type of immortality. Each human body is a custodian of germ-cells, safeguarding them for future generations.

We now know that there has been an uninterrupted sequence of cell-divisions since the beginnings of life on earth, millions of years ago, uniting all living organisms of today—human beings, animals, and plants—with their remotest prehistoric ancestors. This great fact is known as the Law of Genetic Continuity.

Thus, the proved, demonstrable facts of cytology show very clearly that the human fertilized ovum, like every other fertilized ovum, transmits a heredity from two parental lines of germ-cells to every body-cell and to every germ-cell that may be produced by the repeated divisions (mitoses) of that fertilized ovum. There is no other avenue of heredity. The possibility of the biological transformations of energy, of the growths, and of the specializations in structure and function that characterize the tissue cells of the human body are heritages received by those cells from their originating fertilized ovum.

The inherited dynamic potentialities of health are present in the cells, tissues, and organs of the infant at birth. Under the influence of experience with environment from the moment of fertilization, these inherited potentialities are favored or restricted so that they are more or less completely realized in the later life of the child, youth, and adult. We may differ as to the relative importance of heredity and environment in relation to the health of the individual. We cannot differ in the conclusion that each is of essential importance. Neither can be defective or deficient without damage to health or life. The individual is always a product of both. His body, his mind, his personality, and his character are built out of his heredity under the stimulating, moulding, and developing influence of his experience with his surroundings.

Successful research in human heredity is much more difficult than in plant or lower animal heredity. The "marriage" of plants and of short-lived, rapidly producing animals is easily controlled, their matings may be selected, and their offspring classified and examined. But human matings present obvious limitations to such investigations.

Nevertheless, we know that the laws of Mendel hold for the human being as well as for the plant and the lower animal. It is more difficult and in some respects quite impossible to distinguish pure lines from hybrid ones in human beings. It is difficult and often impossible to find and naturally also to arrange human mating under conditions that will yield data on heredity that may be accurately interpreted. But we know that the laws that we have discussed above apply to human heredity as well as to the heredity of plants and of other animals.

Our present knowledge lists the following characteristics as heritable in man: stature, general body size, weight, color of skin, straight hair, curly hair, other forms of hair, features that characterize the head and its parts, color of eyes, general mental ability, memory, temperament, musical ability, literary ability, artistic ability, mathematical ability, mechanical ability, and longevity.[1]

The heritability of defects and deficiencies that constitute our list of hereditary diseases is omitted because our concern here is with constructive hygiene. Such a list belongs to defensive hy-

[1] This classification is patterned after that of W. E. Castle, *Genetics and Eugenics* (Harvard University Press, 1930), p. 343.

giene. The inheritance of disease will be discussed in subsequent chapters concerned with the agents and influences that injure health.

The individuality of the chromosomes, their ancient history and genetic continuity, the mechanical precision of their behavior in fertilization, mitosis, and meiosis, and particularly their amazing segregation, reduction in number, and random distribution prior to fertilization, are scientific facts which establish and limit the possibilities of constructive hygiene in heredity.

There is no way in which a new chromosome, chromomere, or chromiole may be calculatingly added to a haploid or diploid group. There is no way in which to add a new gene. Whatever may be the something that determines the heritability of a character, it is not an entity that can be added or acquired by any method now known.

We know of no way in which to improve the quality of a gene or a group of genes. The proof of the inheritance of normal acquired characters has not been produced. There is some evidence considered elsewhere that seems to show that genes may be damaged by poisons circulating in the blood. If this is true, it follows that acquired injuries to germ-cells may be followed by the inheritance of the acquired alterations of characters produced by those injuries. This would be the inheritance of acquired damaged characters.

The heredity of a given individual is the product of two single groups of chromosomes, one maternal and the other paternal. It follows theoretically that the heredity of children could be planned by selecting parents with the dominant genes desired. As a matter of fact, we know too little about human heredity to enable us to select carriers of dominant genes. Furthermore, our instincts, emotions, customs, social standards, and religious beliefs limit the extent to which such selections could be made if we did know how. Finally, we know that the heritage of cells that constitute the infant at birth is a heritage of possibilities. These possibilities may be realized only in case the infant is placed in surroundings and under conditions that give all its cells and all its organs through succeeding years the structural and functional experiences they need for development, for co-ordination, and for integration. If the sound, complete heritage of a newly born infant is given appropriate experience with environment, the re-

quirements of physical, mental, and social hygiene will be met. There will follow a proportionate quality of physical, mental, spiritual, and social health.

Obviously, there are three main problems in the constructive, voluntaristic hygiene of heredity. One problem is that of the maturing or mature individual whose concern is to safeguard the sound heredity of which he is custodian. The second is the problem of the individual who is concerned in providing his children with a heredity that will make for the development of physical, mental, and social health. The third problem in the constructive hygiene of heredity is a problem of the mature adult, the family, and the public. This problem is concerned with the prevention of the transmission of vicious heredities, and with the encouragement of the transmission of favorable health heredities.

The facts that have been presented in the foregoing pages apply inexorably to these problems. Every one of us is a product of heredities and the energies of those heredities that were brought together by the two particular germ-cells from which he came.

We had no control over the transmission that gave us the gift of life and its energies, the gift of native potentialities for growth, and for education of mind and of body, and the gift of innate possibilities of development of social personality and character. All of these have an intimate and determining influence on health, whether it be somatic, mental, or social health.

The earlier years of the life of the individual are years of dependence. As an infant, child, adolescent, and youth, his mental hygiene, his body (or somatic) hygiene, and his social hygiene are joint products of the influence of the heredity furnished by his parents and of the environment provided by his parents, his family, and his community. He gradually and imperceptibly acquires the relative independence of maturity. His program of hygiene has been a program provided by others, wittingly or unwittingly. There is no such thing as prenatal hygiene, infant hygiene, child hygiene, or adolescent hygiene except as furnished thoughtfully or accidentally by maturity. When the individual reaches the relative independence of maturity, he is very likely to continue the habits that he has learned in his previous periods of decreasing dependence. The main objective of informational hygiene is to influence intelligent maturity to improve its attitudes and habits of health.

To state that these years of dependence are years of unaccountability would be wrong. The arrival of individual responsibility is slow and its beginnings are somewhere in the period of childhood. Its growth is gradual. But no one of us is ever wholly independent. To some degree responsibility for the production, maintenance, and defense of the health of the individual is always an obligation of the group in which he lives and of the society of which he is a part. The independence of the individual in matters of health, as in other matters, is never complete.

But the fact of dependence, beginning as it does with the utter parasitic dependence of prenatal life and the complete helplessness of infancy, does not justify an attitude of irresponsibility and unconcern by the maturing or mature individual for the grade or quality of physical, mental, or social health which he achieves and maintains. A scientific attitude of mind, a discriminating judgment, and a practice of reasonable health habits will develop and defend the inherent health possibilities of the individual and help him serve his family, society, and himself. He may thus achieve usefulness and mental and spiritual happiness. This is the solution of the health problems inherited by the individual that should be always attempted.

In the ordinary course of events young adults marry and have children with little or no thought as to the heritages involved. The possibilities of sound or damaged offspring are not often considered. When he thinks of it, every intelligent, fair-minded person is anxious that the heritage that he passes on to his children shall be sound. No normal woman and no normal man would knowingly bring a new life into the world handicapped by an inferior heritage. Every reasonable man and every reasonable woman planning marriage would see to it that the children produced were strong, vigorous, healthy, long-lived, and of high intelligence, if they knew how to guarantee such a result.

If in some effective way parenthood could be limited so that all children would be born of normal fathers and normal mothers, there could be no abnormal mothers and no abnormal fathers and no abnormal children after a sufficient number of generations had come and gone to remove all the hybrid combinations of good and bad heredity. If marriage were permitted only to mates that were tall, strong, vigorous, highly intelligent, and long-lived, there would come a time when all the world would have in it only men

and women who were tall, strong, vigorous, highly intelligent, and long-lived. All complementary recessives would disappear and there would be left no human germ-plasm containing antecedent chromosome material from which such recessives could be restored.

It is obvious that no such wholesale program of constructive heredity will ever go into operation.

If you as an individual select and win a mate of fine, sound mind, of wholesome, independent character, of vigorous, healthy body, who has an ancestry of equal qualities, and if you give as good qualities yourself, you are reasonably safe in the expectation that your children will exhibit those same qualities. With the right sort of environment, especially in the home, the children of such a line will become men and women of vigorous, enduring mental, physical, and social health.

List of Heritable Human Health Characters and Health Qualities

Castle distinguishes provisionally human traits that are inherited as "(1) blending (probably involving multiple factors); (2) clearly Mendelian (involving a single genetic factor); (3) Mendelian and sex-linked; (4) probably Mendelian but with dominance imperfect and uncertain; and (5) hereditary but to what extent uncertain."[1]

An examination of various listings[2] of human heredities supports the following classification:

1. Those that signify somatic health
   a) Normal structure and function (normal anatomy and physiology)
   b) Normal growth and development
   c) Stature, size, body build
   d) Strength

[1] W. E. Castle, *Genetics and Eugenics* (Harvard University Press, 1930), p. 343.

[2] Castle, *op. cit.;* Charles Benedict Davenport, *Heredity in Relation to Eugenics* (Henry Holt & Company, 1911); Edwin Grant Conklin, *Heredity and Development of Men* (Princeton University Press, 1930); Raymond Pearl and Ruth DeWitt Pearl, *The Ancestry of the Long-Lived* (Johns Hopkins Press, 1934); C. C. Hurst, *The Mechanism of Creative Evolution* (Macmillan, 1932), p. 225; Frances Galton, *Hereditary Genius* (Macmillan, 1914).

   e) Vigor, general bodily energy
   f) Immunity, resistance to disease
   g) Longevity

2. Those that signify mental health
   a) Normal mind, general mental ability
   b) Educability
   c) Superior intelligence
   d) Memory, musical ability, literary ability, artistic ability, mathematical ability, calculating ability, mechanical ability

3. Those that signify social health
   a) Includes 1 and 2 above
   b) Leadership qualities
   c) Temperament

CHAPTER XII

THE HYGIENE OF HERITAGE

The total heritage with which a human life—every human life—begins is a microscopic bit of living protoplasm containing a nucleus that is composed of the combined protoplasms (the cytoplasms and the nuclei) of two living parental germ-cells, an egg and a sperm. The reader of these lines, as well as the writer, began his existence as such a living heritage. His body, mind, and social personality are products of the growth and development of the body, mind, and personality of a parental egg-cell and a sperm-cell fused to form the body, mind, and personality of the bit of protoplasm that for a short few moments constituted all there was of him.[1]

It is the purpose of this chapter to assemble and very briefly describe a number of diagrams illustrating the growth and development of this originating germ-cell and the specialization of its enormous progeny of cells into tissues and organs. This growth, development, and specialization are products of the autonomic hygiene of germ-cell heritage that finally equip the whole child for birth into a social world in which it will continue to be utterly dependent upon the favor of environment and favorable experience with environment for the production, improvement, maintenance, and defense of its somatic, mental, and social health.

The growth and development of the fertilized ovum are illustrated by Figures 21–27. The specialization of the body-line cells (somatic cells) into tissue cells is illustrated in Figures 28–32. The specialization of organs is described in Figures 33–37.

[1] See Edwin Grant Conklin, *Heredity and Environment in the Development of Men* (Princeton University Press, 1930), chap. i.

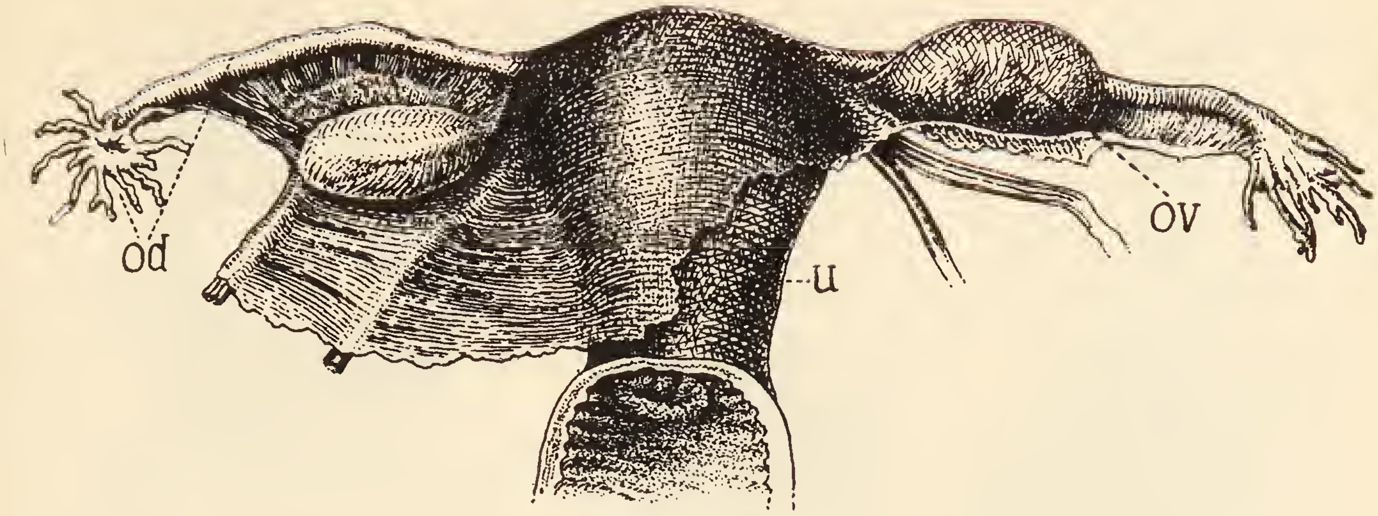


Fig. 21.—Diagram of the human ovaries, *ov*. When eggs are ready for fertilization they leave the ovary, bursting from the Graafian follicles (see Fig. 22) through its surface, and find their way into the outer opening of the oviduct, *od*, or Fallopian tube. They then pass through the oviduct into the uterus, *u*. Fertilization takes place under normal circumstances in the oviduct, the motile sperms finding their way through the uterus and into the oviduct, where one of them meets and penetrates the surface of an egg. After the union of the sperm and egg the fertilized ovum passes from the oviduct into the uterus, lodging on its inner surface. Here the egg, having already begun to divide and already constituting a living embryo, finds the environment essential to its life, growth, and development.

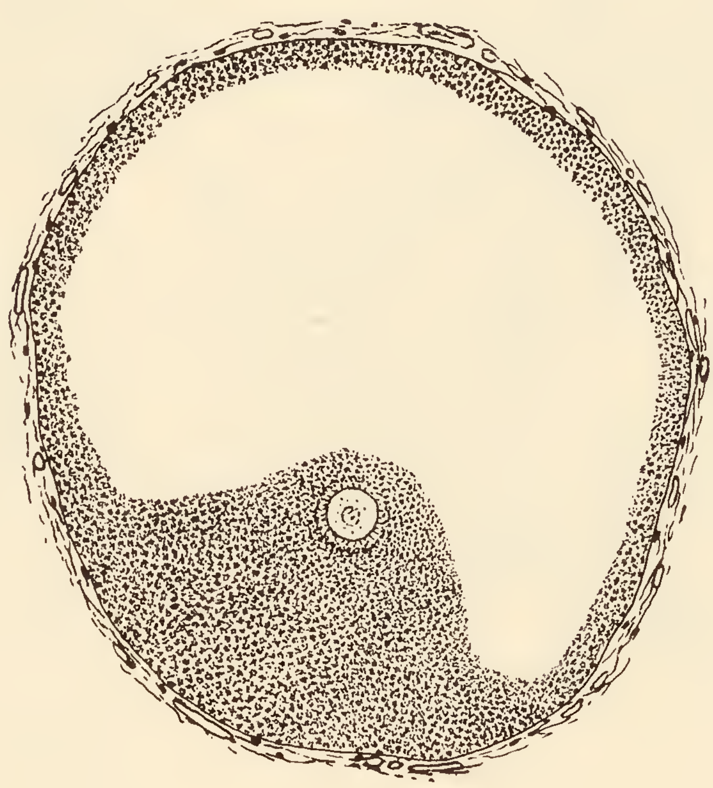


Fig. 22.—Ripe human ovum imbedded in a mass of cells, the Graafian follicle. The follicle develops under the surface of the ovary. When the follicle bursts, the egg emerges and finds its way into the oviduct as described under Figure 21.

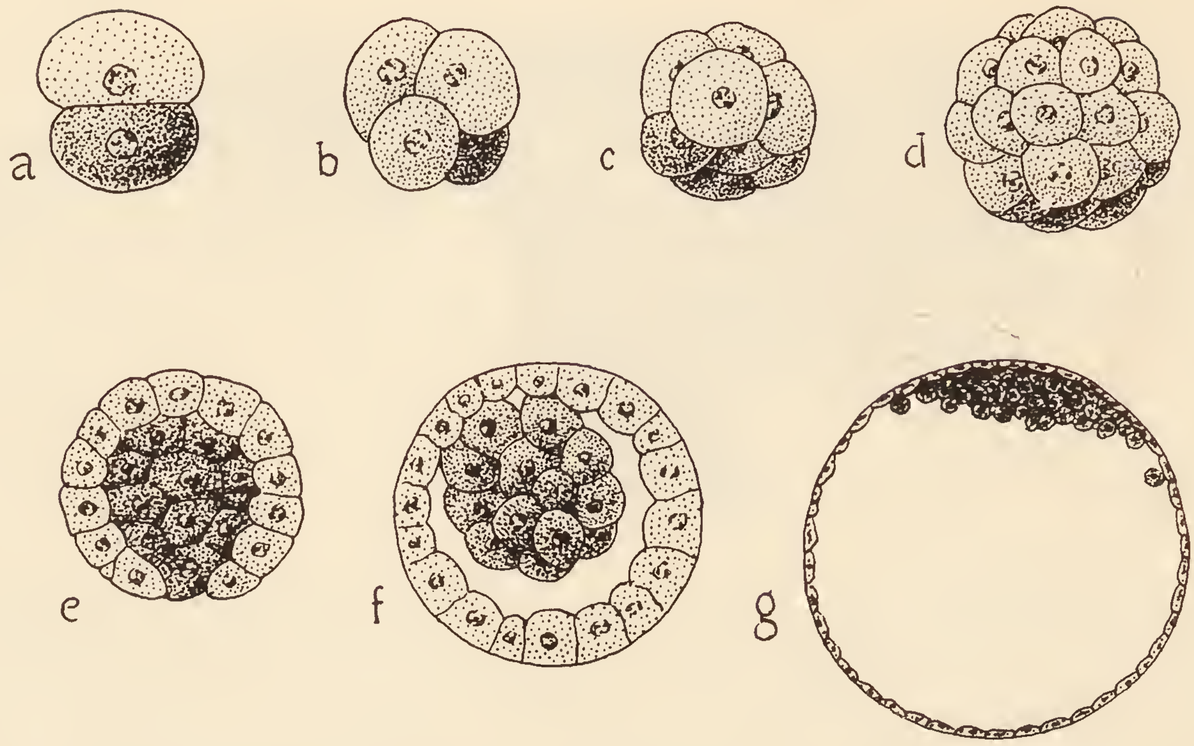


FIG. 23.—Diagram of the early development of the rabbit, which probably resembles that of man. After fertilization (see Fig. 13) the egg divides repeatedly (see Fig. 14), forming in *g* a sphere of cells, the trophoblast, enclosing the inner cell mass darkly shaded. For later stages in man see Figures 25 and 26 (Van Beneden).

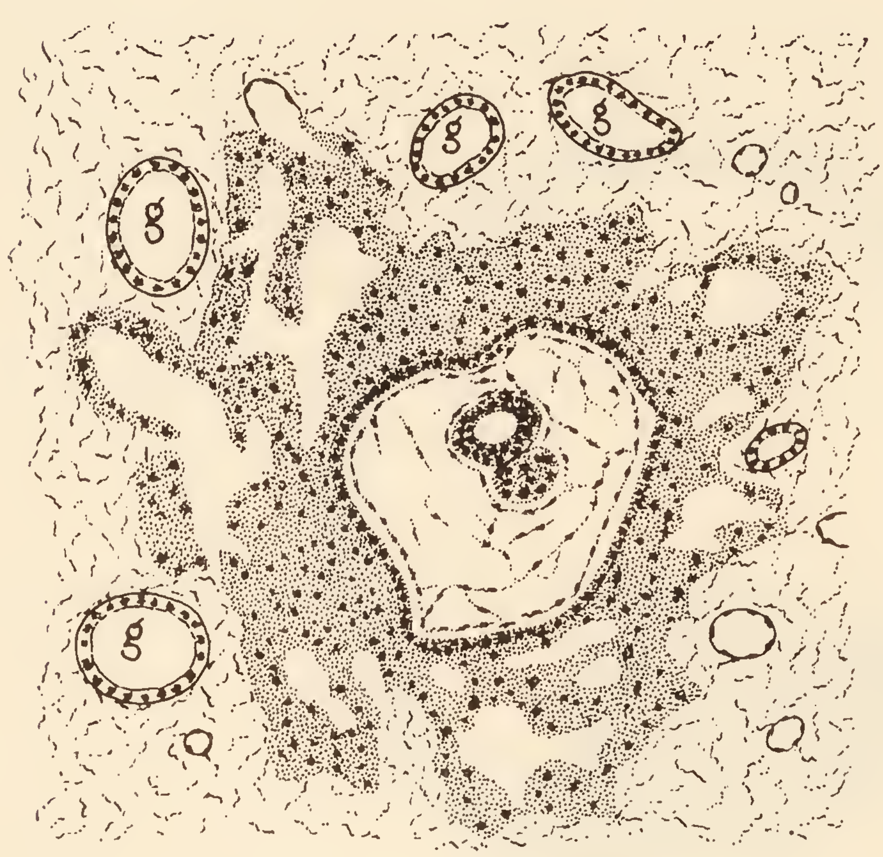


FIG. 24. — Youngest known human embryo, about 11 days. The inner cell mass (represented by darker cells in Fig. 23, *g*) is contained within the irregular ring of cells in the center of the diagram. It gives rise to the embryo and a portion of the enveloping membrane. The ring of cells in Figure 23, *g*, known as the trophoblast, is giving off masses of cells (shaded in the diagram above) which penetrate the maternal tissues of the uterus and function in the absorption of nutritive materials brought them by the mother's blood and lymph circulations, and in the removal of wastes that are carried away by the mother's venous blood. *g* are glands in the wall of the uterus. The blood vessels of the uterine wall are represented as thin-walled circles. (Muller and Streeter, redrawn from Dodds.)

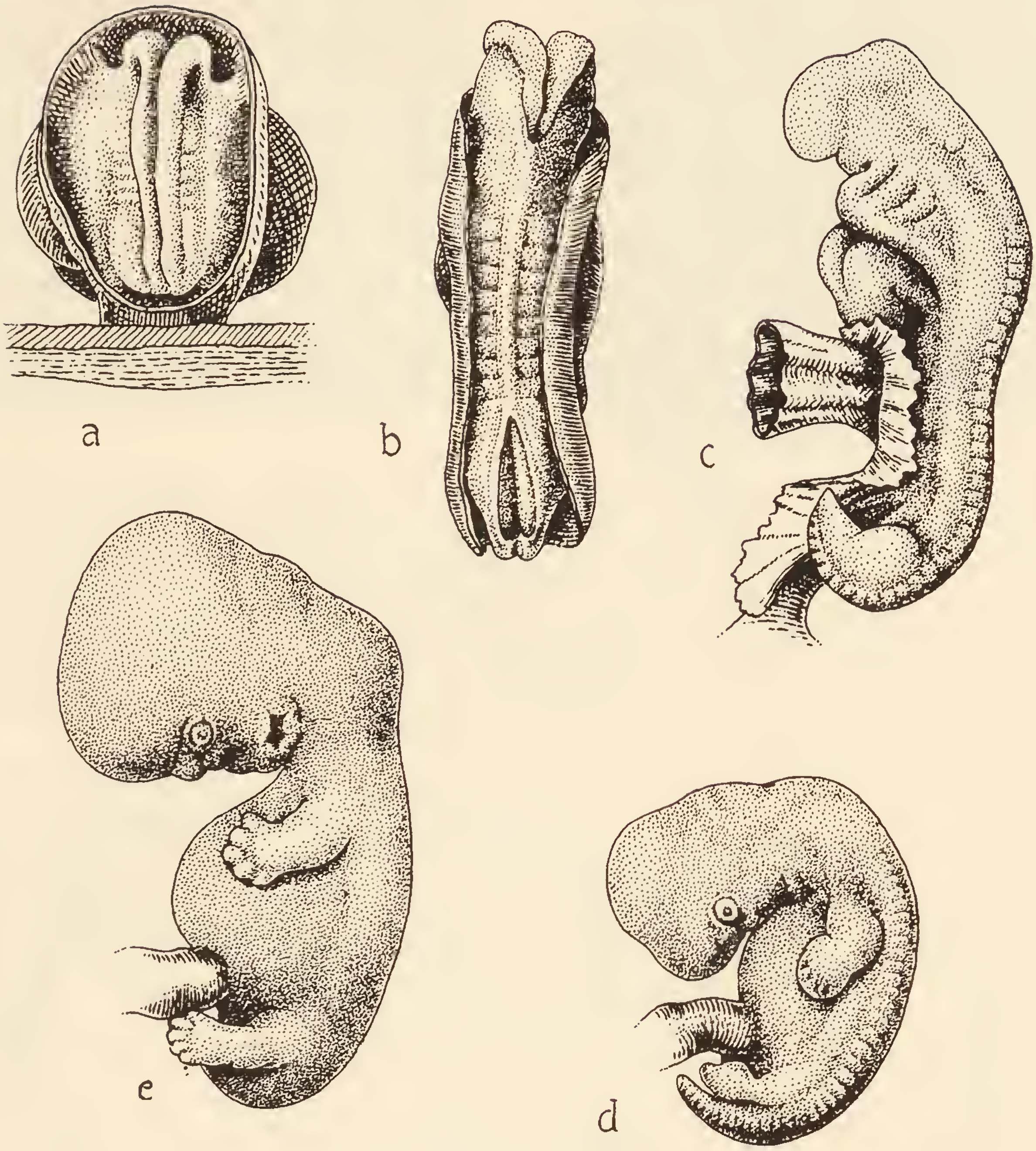


Fig. 25.—Diagrams of different stages in human growth and development. In all cases the enclosing membranes have been removed, at least in part. Approximate age of *a,* 26 days; *b,* 28 days; *c,* 4½ weeks; *d,* 42 days; *e,* 49 days. (*a,* Keibel and Elze; *b,* Eternad; *c, d,* and *e,* His.) *c, d,* and *e* show the umbilical cord through the blood vessels of which the fluid, food, vitamins, and inorganic salts are transported to the unborn child from the blood circulation of the mother. Excretions and wastes are carried away through the cord (see Fig. 26).

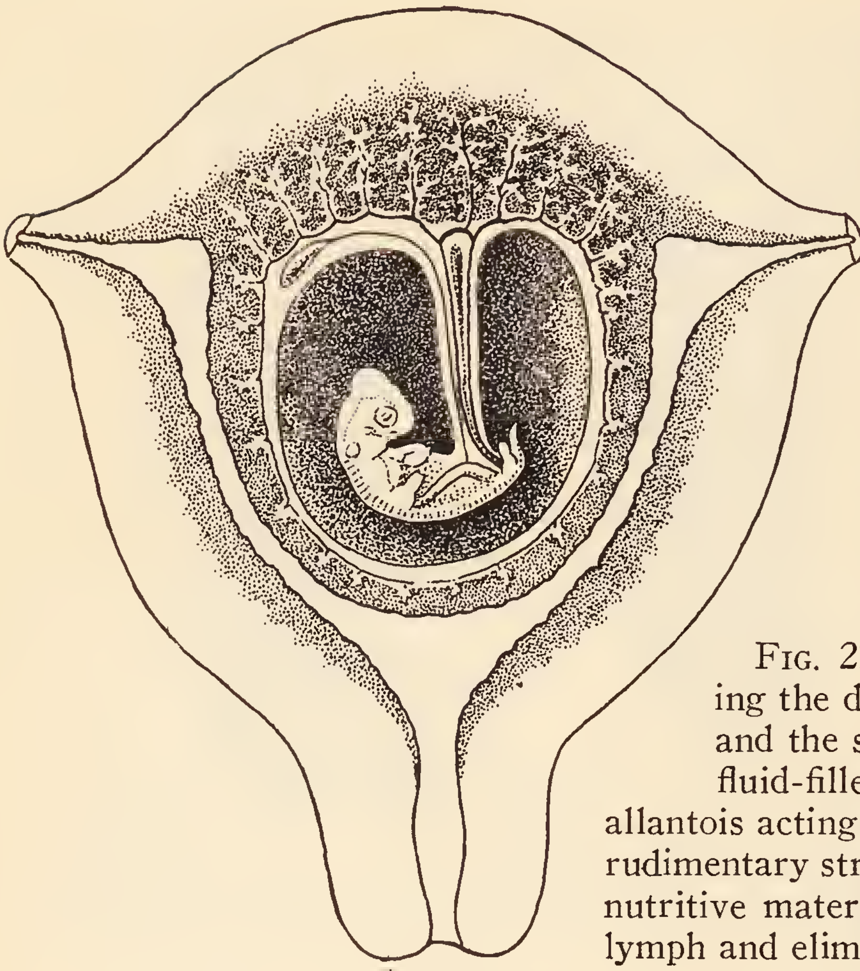
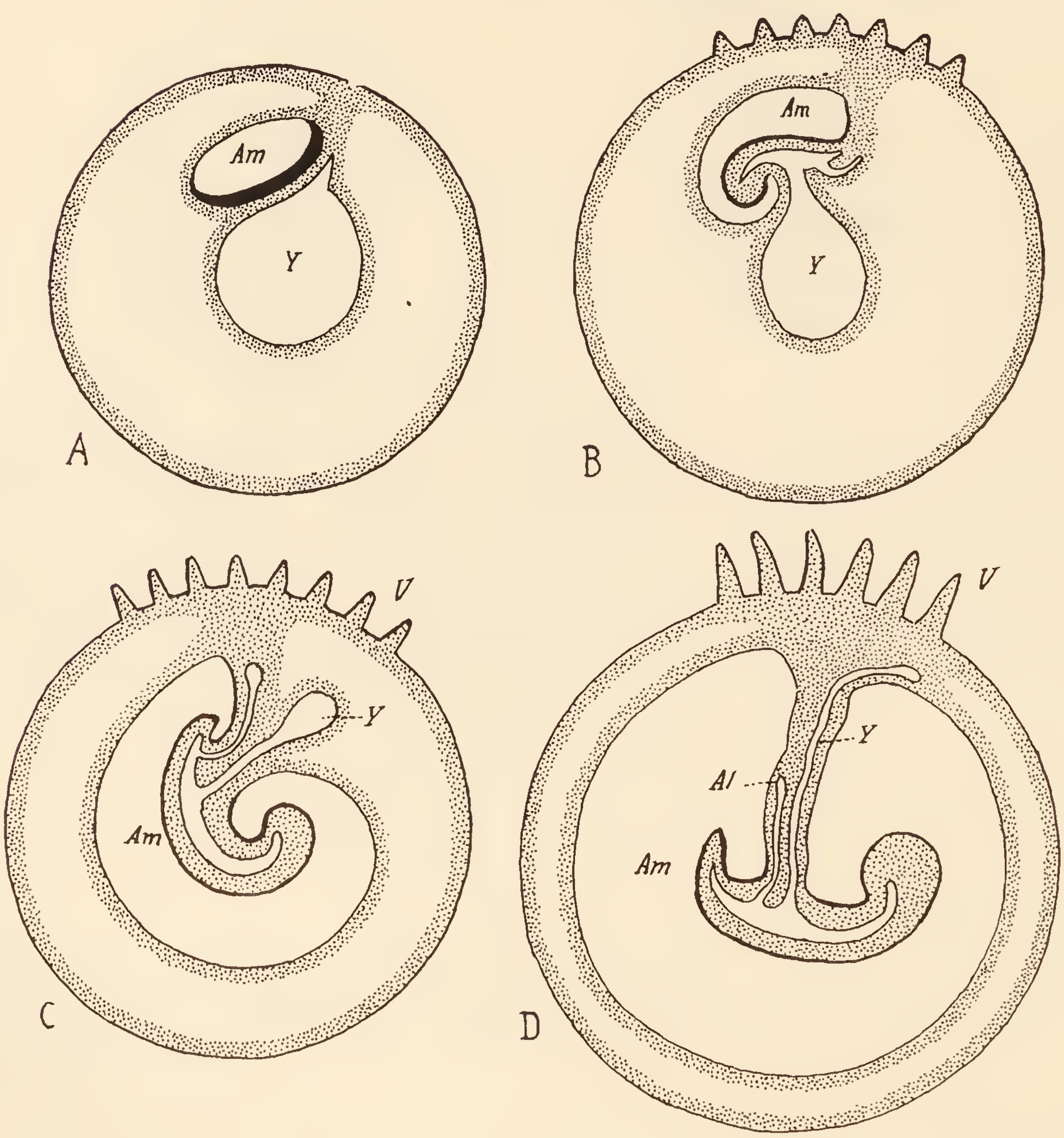


Fig. 26.—Diagram of human embryo of about 7 weeks showing its relation to the uterus (after Thomson). The shaded portion comes away with the child. The umbilical cord is shown connecting the embryo with the placenta through which the embryo receives its nutritive material from the blood supply of the uterus and through which also the embryo is relieved of its excretions (see also Fig. 27).

Fig. 27 (below).—Diagrams illustrating the development of the human embryo and the surrounding membranes: *Am,* the fluid-filled cavity of the amnion; *Al,* the allantois acting as a bladder; *Y,* the yolk stalk, a rudimentary structure; *V,* the placenta absorbing nutritive materials from the parental blood and lymph and eliminating wastes.



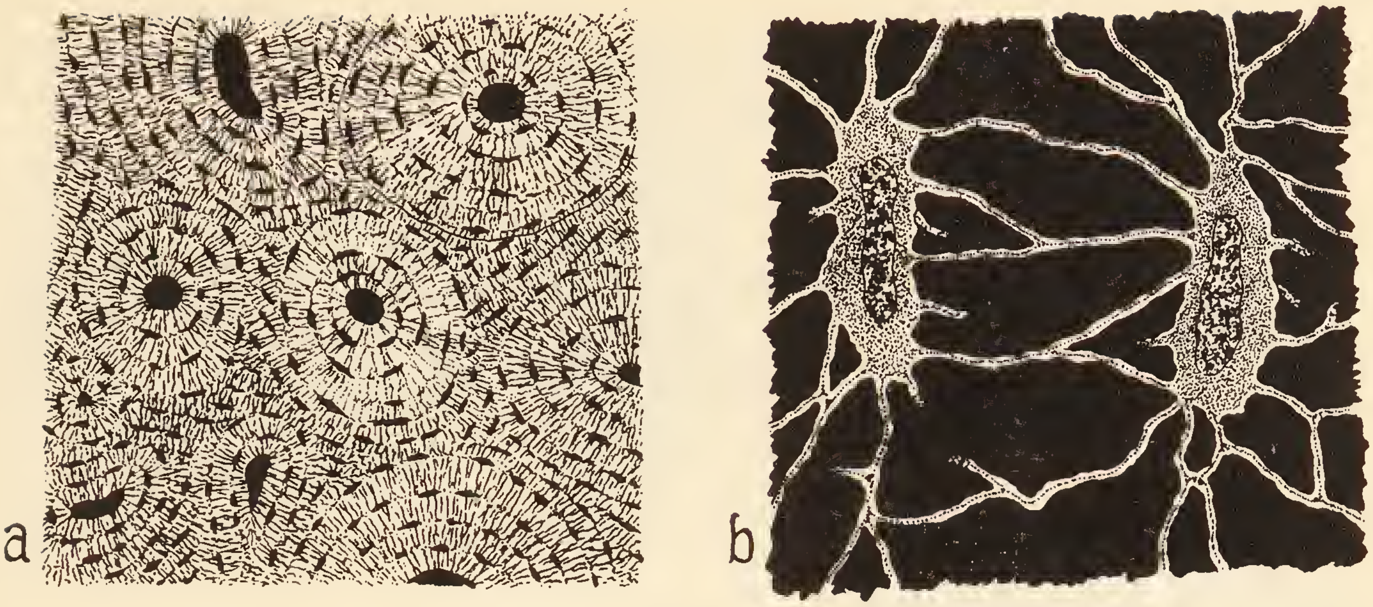


FIG. 28.—Structure of bone: *a,* cross section of human humerus; *b,* diagram of two bone-cells with communicating branches, the black material representing bone. The body-cells (somatic cells) produced by repeated divisions of the fertilized ovum have become specialized into these bone tissue cells. The bone structure is formed by the deposit of calcium salts secreted by the bone-cells.

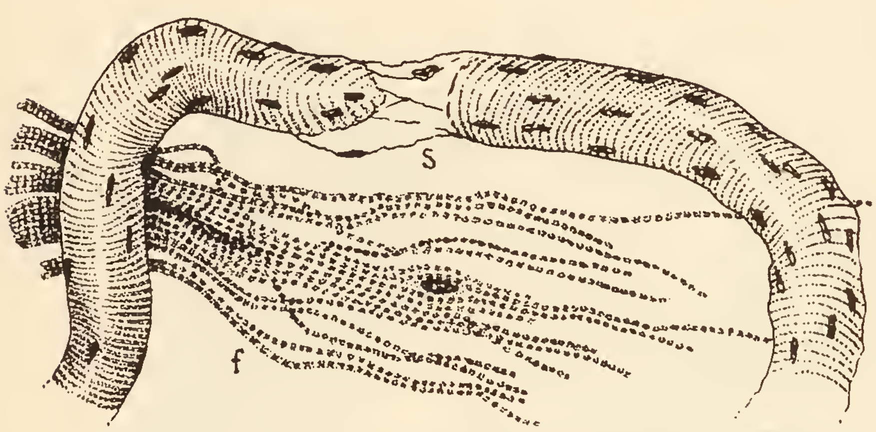


FIG. 29.—Human striated muscle fibers enclosed in a sheath, *s; f* shows fibrils of which the fiber is composed (slightly modified after Maximow), another example of the specialization of the body-line cells produced by the repeated divisions of the originating fertilized ovum.

FIG. 30.—Smooth or unstriated muscle-cells from the human intestine.

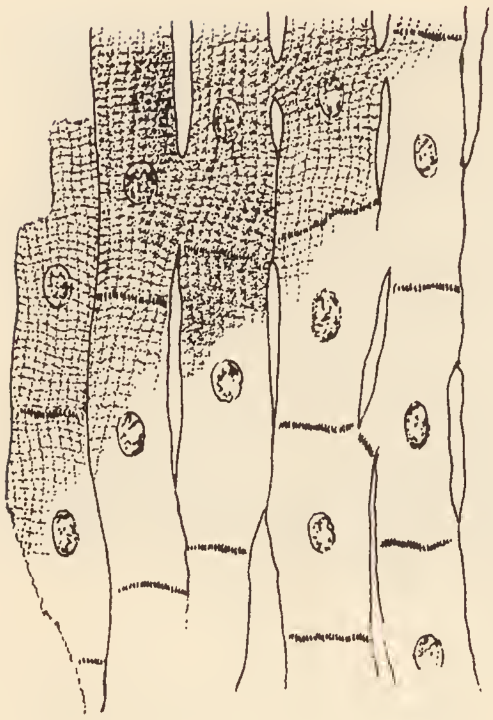


Fig. 31.—Small portion of heart muscle showing striation and the union of adjacent cells (modified from Schweigger-Seidel).

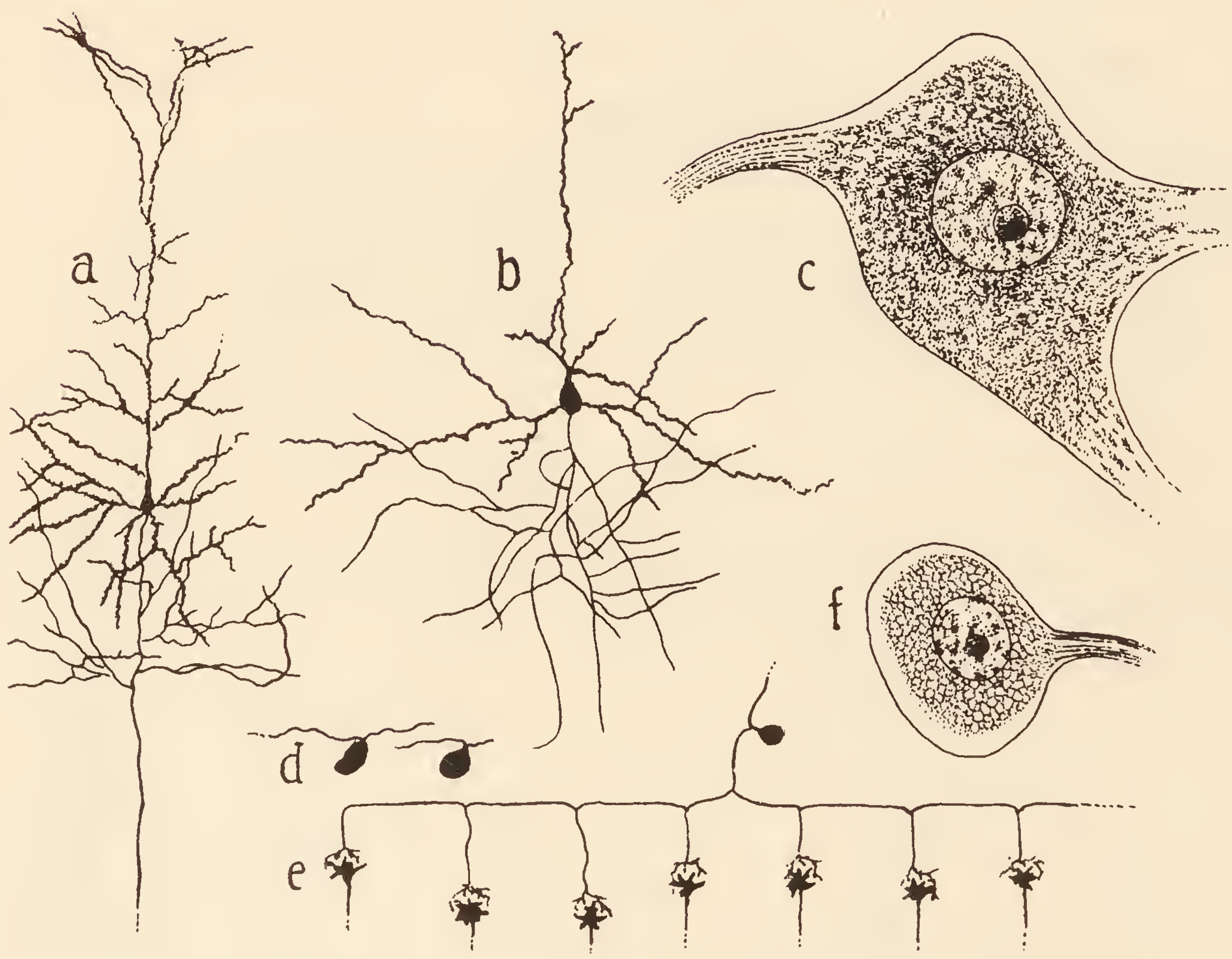


Fig. 32.—Nerve-cells, *a* and *b*, from human brain; *c* and *f*, enlarged nerve-cells from dog; *d*, bipolar cell from retina; *e*, collateral cells which convey impulse to many other nerve-cells through lateral branches. (*a*, from Raymón y Cajal; *b*, from Koellicker; *c* and *f*, from Schafer.)

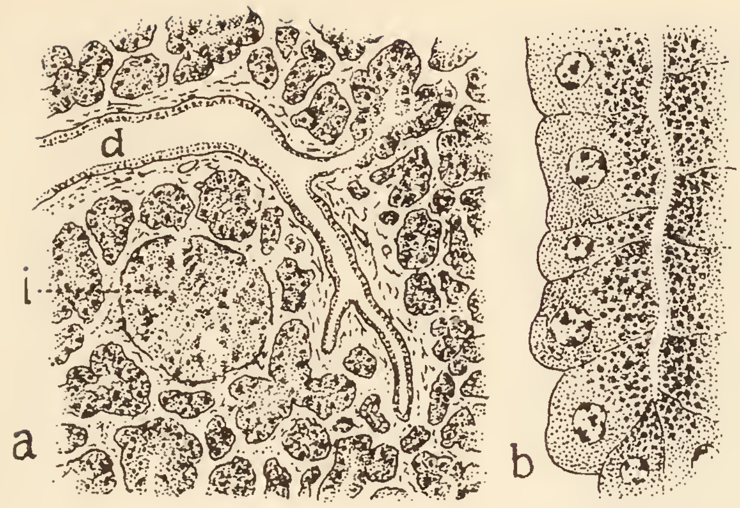


FIG. 33.—Section through portion of human pancreas: *a* shows arrangement of secreting cells of pancreas around the duct *d,* containing *i,* a ductless gland, an island of Langerhans; *b,* more highly magnified cells showing pancreatic secretions in the form of fine droplets previous to secretion into the lumen of the gland.

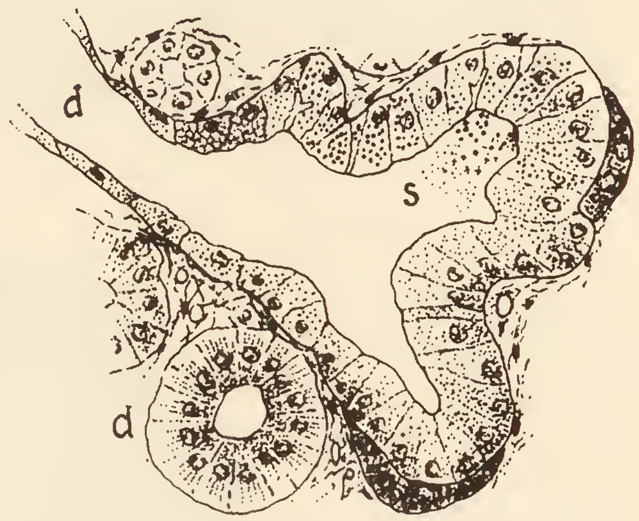


FIG. 34.—A small portion of human salivary gland where a few cells at *s* are discharging their secretion, which is carried off through the duct *d.*

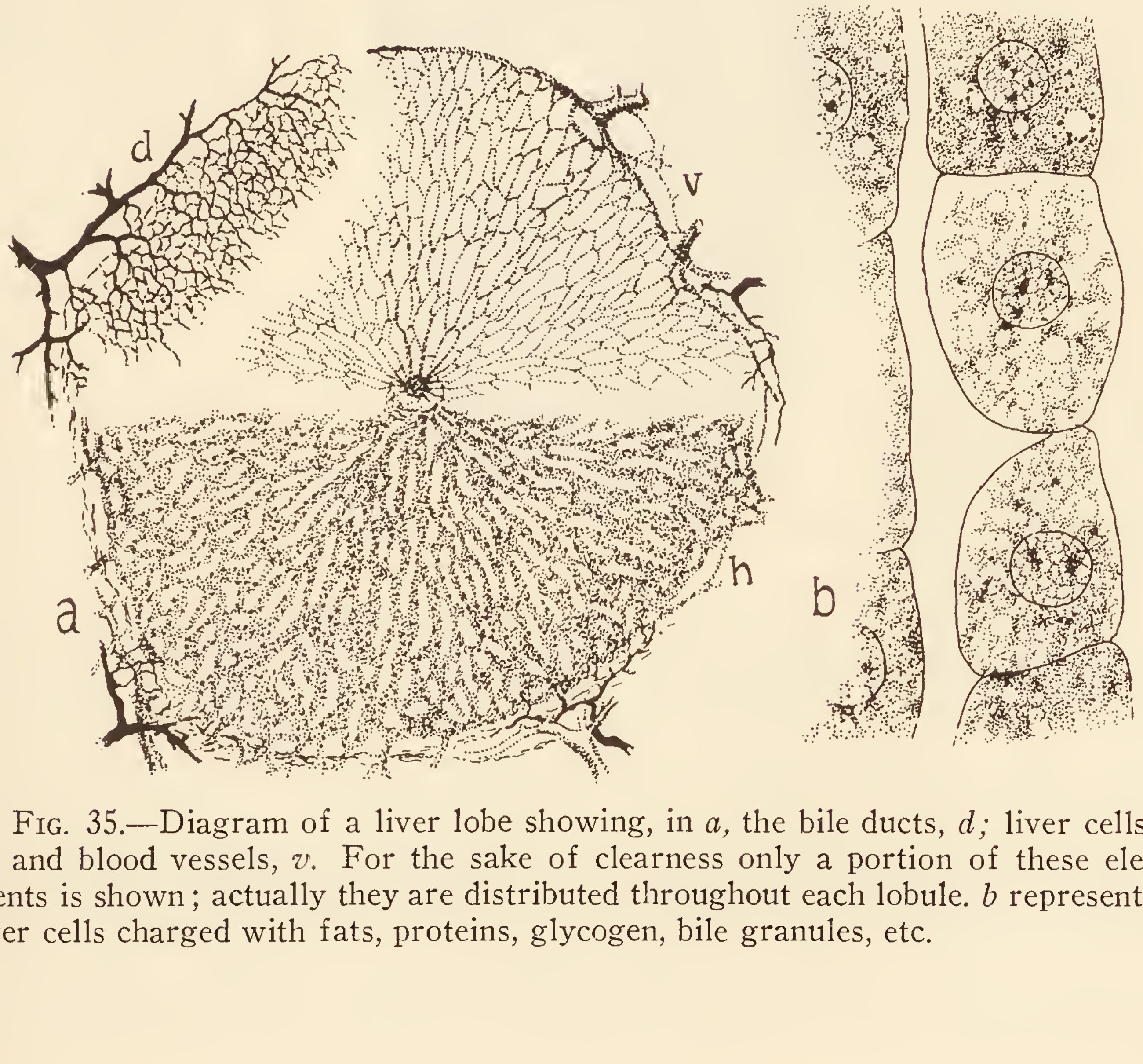


FIG. 35.—Diagram of a liver lobe showing, in *a,* the bile ducts, *d;* liver cells, *h;* and blood vessels, *v.* For the sake of clearness only a portion of these elements is shown; actually they are distributed throughout each lobule. *b* represents liver cells charged with fats, proteins, glycogen, bile granules, etc.

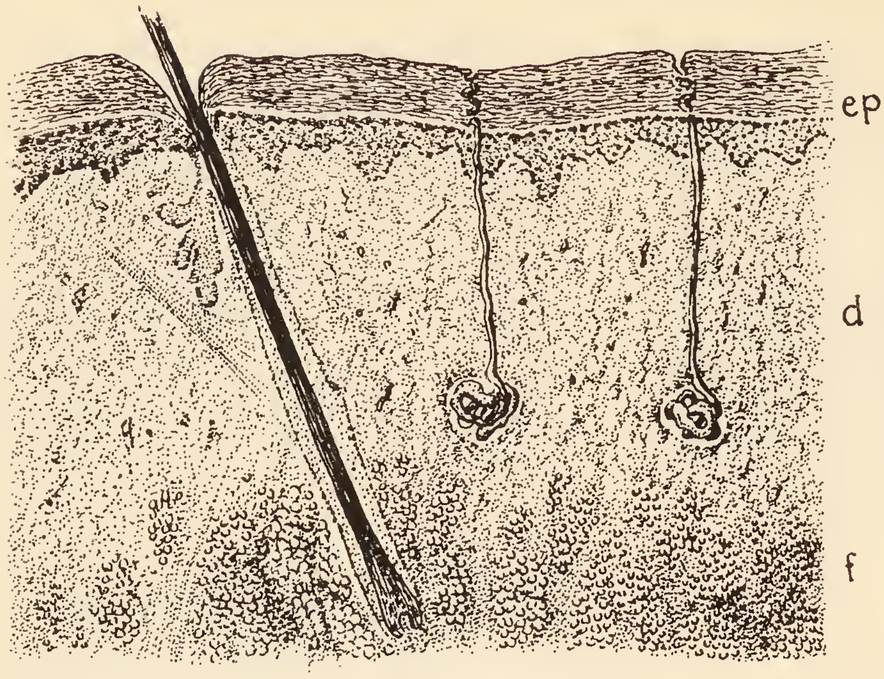


FIG. 36.—Section through human skin showing hair; the sweat glands; the epidermis, *ep;* the dermis, *d;* and an underlying layer of fat, *f.*

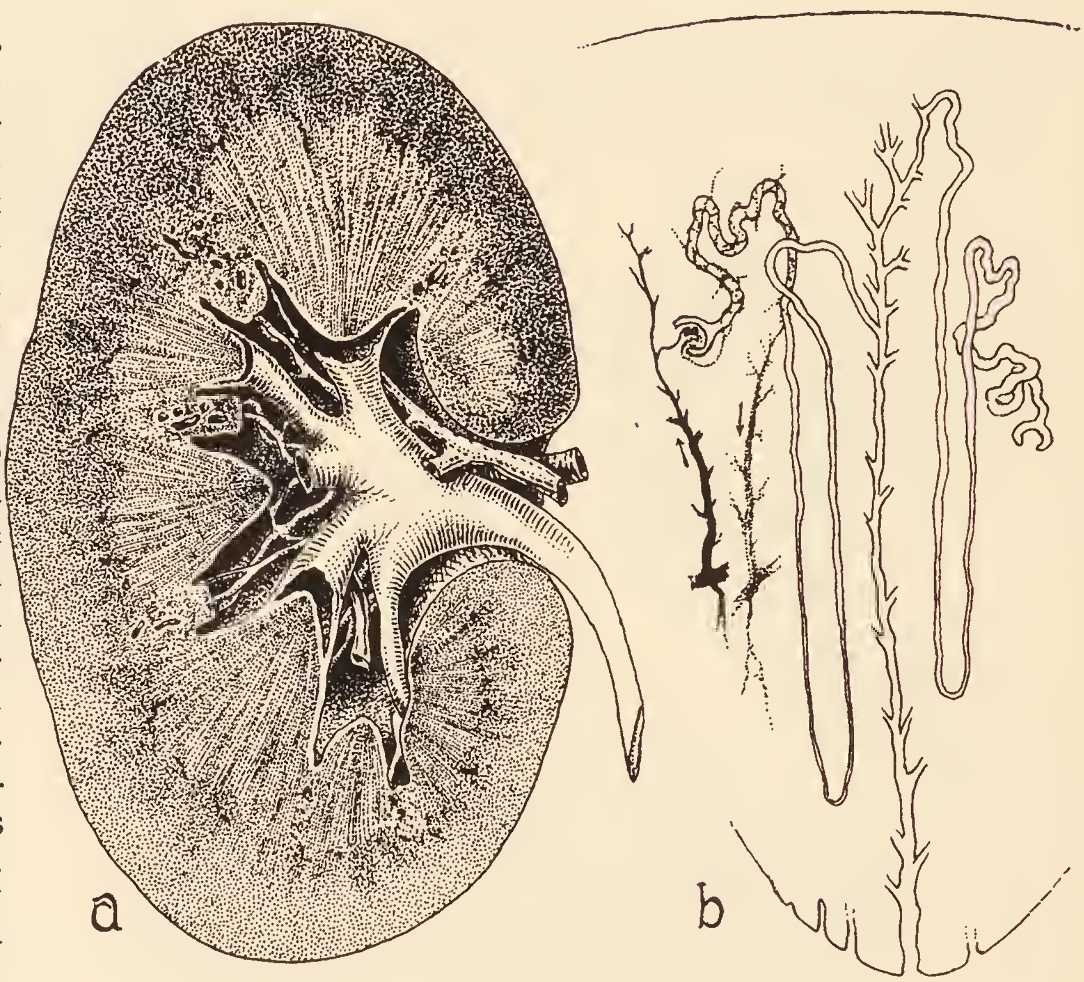


FIG. 37.—Diagram of kidney: *a,* a longitudinal section near the median line; *b* shows the more important details of the kidney structure. The black detail in *b* represents one of the small arteries that bring blood to the capillaries of a glomerulus. The fine dotted detail leading away from the glomerulus represents a small vein draining the capillaries of the glomerulus. It drains also the capillaries of the upper part of the small urinary tubule that drains the glomerulus of the excretions that have been removed through the glomerulus from the blood brought to it by the small artery to which reference has been made. The cells in the walls of the upper part of this small tube are concerned with the removal of excretions brought to them by the blood stream of the kidney. Thus the small tube carries excretions from the blood brought to the glomerulus and also from the blood brought to the upper part of the small tube itself. The small tube leading from the glomerulus joins a larger tube into which many other similar small tubes discharge their contents of urine. The larger tube empties into the ureter, which, in turn, empties into the bladder. The outer zone in *a* contains blood vessels and glomeruli. The converging lines seen in the seven pyramids in *a* are formed of urinary tubules. The white branched detail is the ureter. (See pp. 201 ff. for description of the essential importance of the kidney as an excretory organ.)

CHAPTER XIII

NUTRITION: AN ESSENTIAL PRINCIPLE OF CONSTRUCTIVE HYGIENE—PRIMARILY A PRINCIPLE OF CONSTRUCTIVE SOMATIC HYGIENE

All the tissue cells of the human body are more or less completely surrounded by fluid. This fluid is lymph that comes from the blood in the capillaries. The fixed tissue cell, then, lies in fluid.[1]

Because of the physical and chemical processes of imbibition and osmosis, the cell absorbs a part of this fluid through its surface. It also absorbs chemical compounds dissolved in the lymph. The cell uses the water and chemicals it absorbs. And when there is no further use for them, the cell eliminates the fluid and altered chemical compounds through its surface back into the lymph. This process of absorption, use, and elimination constitutes the nutrition of the cell.

Nutrition and metabolism are words having the same meaning. General nutrition or general metabolism includes all the changes that take place in the foodstuffs from their absorption from the alimentary canal to their elimination from the body in the excretions. The oxygen absorbed from the air-spaces in the lungs is carried to the tissue cells, where it becomes a part of the nutritional process.

The growth of the human body, its weight, its physical and mental energy and vigor, and its vital endurance are products of its own chemistry. Every tissue cell is a constructing and manufacturing chemical and physical laboratory. This is another way of stating that good health is a product of good physiological chemistry. It is another way of stating that good health is a product of good synthetic chemistry within the tissue cell. The growth, weight, and function of the body as a whole are summations or composites of the growths, weights, and functions of the tissue cells of the body. The body is a collection of co-operating, integrating organs. The organs of the body are made up of tissues, and the tissues are composed of cells. The muscles are

[1] The physiological facts presented in this chapter follow largely the *Text-book of Physiology* by W. H. Howell, published by W. B. Saunders Co., seventh edition, and corrected from eighth, ninth, and tenth editions.

organs. The eyes, the heart, the nerves, the stomach, and the kidneys are other examples of organs. An organ is made of combinations of tissues. These combinations include muscle tissue, nerve tissue, connective tissue, glandular tissue, and other tissues, arranged in such a manner as to provide the organ with the machinery it needs for performing its normal functions. These cells and the tissues they form are the equipments, machineries, and furnishings with which the organs manufacture their special products and carry on their special operations.

It is obvious that these tissue-cell laboratories, these microscopic construction-plants and factories are absolutely dependent upon the chemical supplies that are brought to them. Every tissue cell is dependent upon its chemical intake for its "raw" structural and functional material. No tissue cell could live without these chemicals. Under normal conditions an adequate supply of these chemicals gives the tissue cell the structural completeness, the growth, and the functional energy and power that combine to make it a healthy cell. A healthy organ and a healthy body are products of healthy cells.

The chemicals that have been proved necessary to health and to life are carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur, chlorine, sodium, potassium, calcium, magnesium, iodine, and iron. Certain other chemicals are essential to certain forms of animal and vegetable life. The chemicals noted above are essential to human life and, therefore, to human health. These chemicals are taken into the body by way of the food we eat, the water we drink, and the air we breathe. The soil and the air are the ultimate sources from which these chemicals are secured. All food comes originally from the air and the soil. All water and the oxygen supplied for respiration are furnished from the air and from the soil.

Ultimate source of food.—The food consumed by human beings is of animal and vegetable origin. The animals that furnish food for human beings are for the most part dependent upon plant life for their food supply. The plant kingdom is the ultimate source of human food.

Plants secure their food from the air and from the soil. Plants with green leaves take carbon out of the carbon dioxide of the air and store the carbon in the tissues of the plant. The oxygen that is released by this treatment of carbon dioxide in the green leaf is

returned to the air. This chemical process is carried out by the chlorophyll granules in the leaf acting under the influence of the sun's rays. The process cannot take place in the absence of chlorophyll and it cannot take place in the absence of sunlight. This process is called photosynthesis.

Chemicals found in plants.—Plants take compounds of carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur, chlorine, sodium, potassium, calcium, magnesium, iodine, and iron out of the soil through their roots. Other chemicals are secured by plants from the soil, but the chemicals noted above are the chemicals that must be found in food if it is to sustain human life and support human health.

These chemicals occur in various chemical compounds in the soil. They are dissolved in the moisture of the soil. The water circulation of the plant withdraws these chemical solutions from the soil through the plant roots into the tissues of the plant. The tissue cells of the plant receive these chemical supplies from the soil and from the air and out of that chemical material they build their own cell structure and manufacture their own cell products. The tissue cells of Mendel's garden pea build pea plants and manufacture peas that may be eaten by human beings or by other animals. The tiny tissue cells of the California Sequoias have built trees that are three hundred feet high and vigorous and thriving today, more than twenty-five hundred years since their first green shoots escaped the appetite of browsing deer while the Pharaohs were ruling Egypt. The plant cell manufactures our green and other vegetable foods, our fruits, melons, nuts, sugars, cereals, and breads.

Our meats are for the most part from animals that live on plants. All our milk and milk-products are manufactured by the tissue cells of animals. They are manufactured out of the plant food of the animal. It is obvious, therefore, that in general the chemistry of the human body is a product of chemicals taken by plants from the soil and from the air and furnished to man directly in vegetable foods or indirectly in food for animals that are in turn used by man as food or as sources of food.

Classification of foodstuffs.—The food compounds that contain the chemicals that are necessary to human life and to human health are found in a very great variety of foods. But the careful analyses of the physiological chemist have shown that these varied

and diversified foods may be briefly classified chemically under the following simple headings: (1) water; (2) inorganic salts; (3) proteins; (4) carbohydrates; (5) fats; (6) oxygen; and (7) vitamins.

Water.—The importance of the water intake of the human body and its relation to health is demonstrated by the various essential services that are rendered by water in the body. Dry food cannot be swallowed until it is first moistened by the water secretions (saliva) in the mouth. It is then swallowed through a tube (the gullet or esophagus) the entire inner surface of which is lubricated by a slippery watery secretion.

The whole purpose of digestion is to dissolve food and change it into a simple appropriate chemical solution that may be absorbed through the walls of the intestines. The digestive juices in the stomach and in the small intestine are fluids that are very largely water. By the time that the eaten food reaches the large intestine it has been dissolved and brought into a solution composed very largely of water. This solution of food is absorbed through the walls of the small and large intestines and reaches the blood immediately or very promptly.

It is then carried by the blood, which is 80 per cent water, to all the organs, tissues, and tissue cells of the body. Every tissue cell is bathed in a watery fluid called lymph. The fluid food of the cell passes in solution from the blood capillaries through the lymph and through the cell wall into the cell protoplasm in obedience to the laws of osmosis and diffusion. The tissue cell is by weight 70 per cent water. All its chemical materials are brought to it by fluids (the blood and the lymph). All its chemical processes depend on water. All its secretions and all its wastes are carried away by fluids. The energy of the tissue cell has been called an "energy of molecules in solution." A man weighing one hundred and fifty pounds is more than one hundred pounds water.

The water supply necessary to meet these demands of the many millions of millions of tissue cells of the body is secured from the water and other fluids we drink and from the water that is present in varying amount in all our semi-solid and solid foods. Bread is by weight from 37 to 50 per cent water; potatoes are 75 per cent; milk, 86 per cent; salmon, 77 per cent; eggs, 74 per cent; butter, 15 per cent; celery, 94 per cent; raw apples, 85 per cent; oranges, 82 per cent; and strawberries, 94 per cent.

Yet the water content of our soups, table beverages, and some solid foods is on the average insufficient to supply the water needs of the tissue cells. It is generally believed that one should drink from six to eight glasses of water a day in the intervals between his meals.

Inorganic foodstuffs.—When animal tissues are burned there remains an ash that is composed of inorganic chemicals. This ash represents the inorganic composition of the tissues that were burned. We know that the inorganic salts constitute from 4.3 to 4.4 per cent of the weight of the human body. This inorganic material includes the chlorides, phosphates, sulphates, carbonates, fluorides, or silicates of potassium, sodium, calcium, magnesium and iron.

The salts are common ingredients of potable water and they are present in all foods. Ordinary table salt (sodium chloride) is the only inorganic salt that is added consciously to our food.

Iodine is present in the thyroid glands and is apparently essential to human health and life. It is found in certain foods and in water.

The inorganic salts "maintain a normal composition and osmotic pressure in the liquids and tissues of the body and by virtue of their osmotic pressure they play an important part in controlling the flow of water to and from the tissues. Moreover, these salts constitute an essential part of the composition of living matter. In some way they are bound up in the structure of the living molecule and are necessary to the normal reactions or irritability. Even the proteins of the body liquids contain definite amounts of ash (inorganic material) and if this ash is removed their properties are seriously altered." The calcium salts furnish material for the growth of the skeleton and are specially important in the coagulation of blood. The salts of calcium, sodium, and potassium are essential to the normal rhythmical contraction of heart muscle, to the irritability of muscular and nervous tissues, and to the permeability of the capillary walls and other membranes. The iron salts produce the hemoglobin of the red blood cell that carries the oxygen absorbed by the lungs to the tissue cells. Iodine is essential to the normal action of the thyroid glands. "There can be no doubt in fact that each one of the salts of the body has a special nutritive value and a special metabolic history. The time will come when the special importance of the salts of

potassium, sodium, calcium, and magnesium will be understood as well at least as we now understand the significance of iron."[1]

Protein foodstuffs.—The foods that contain proteins are called protein foodstuffs. The proteins are chemical compounds that contain carbon, hydrogen, oxygen, and nitrogen. Most of them contain also some sulphur. Some proteins contain phosphorus and others iron.

The proteins supply the nitrogen that is required by the animal tissue cell for its structural existence. Protein foods are the only foods that supply nitrogen. There are many proteins described in organic chemistry. Not all of them are equally important as ingredients of food. The adequate or complete proteins will sustain life. In fact, life will not continue without them. Food restricted to inadequate proteins, like gelatin, will not sustain health or life for very long.

The common foodstuffs that contain adequate proteins are meats, fish, eggs, milk, and milk products. The percentage of protein is low in butter, most vegetables, fruits, breads, and cereals.

Fatty foodstuffs.—There are many fats distributed through the animal and vegetable kingdoms. They are defined by the chemist as "esters of glycerol and the fatty acids." They are fatty acids and glycerin. All fats contain carbon, hydrogen, and oxygen.

The more common foodstuffs that contain fats are fatty meats, cream, butter, cheese, vegetable oils, and nuts.

The fats are used by the tissue cells for the production of heat or energy. They may be stored in the tissues as body fat until such time as they may be needed for the production of heat or energy. They may serve other purposes less well understood connected with the structure of the tissue cell.

Carbohydrate foodstuffs.—The most important carbohydrates are the starches and the sugars. They all contain carbon, hydrogen, and oxygen. The common foodstuffs that supply carbohydrates are vegetables, fruits, cereals, breads, starches, and sugars. When carbohydrate food is eaten it is digested chiefly in the upper end of the small intestine and changed thereby into simple sugars. These simple sugars are absorbed through the walls of the intestines and carried by the blood to the liver in the form of glucose.

[1] Both quotations in this paragraph are from W. H. Howell, *Textbook of Physiology,* seventh edition, chap. xlix.

The liver-cells manufacture a substance called glycogen out of glucose. The carbohydrate foods are the chief sources of glycogen. Glycogen is stored in the tissues chiefly in the liver and muscles whence it is supplied the tissue cells when needed. Glycogen is the great and important source of energy in the tissue cell, especially in the muscle-cell. The oxidation of sugar is an important factor in maintaining body temperature. If carbohydrate food or fats are eaten, the amount of protein food necessary for normal health is reduced. Body fat may be manufactured out of carbohydrate food.

Vitamins.—Recent experiments on the feeding of pigeons, fowls, rats, guinea-pigs, and other animals have taught us that our older knowledge of food requirements with all its important and scientifically accurate detail was, nevertheless, incomplete. The investigations of physiological chemists have shown us within the last twenty years that a dietary of water, inorganic salts, and pure proteins, fats, and carbohydrates cannot maintain life. Such a diet is incomplete even though its ingredients are necessary to health and to life. In 1906, F. G. Hopkins, professor of physiology at Cambridge, England, stated that "no animal can live upon a mixture of pure protein, fat, and carbohydrate, and even when the necessary inorganic material is carefully supplied the animal still cannot flourish." In 1911, Casimir Funk gave the name *vitamin* to a substance which he found in the outer layers of the unpolished rice grain. Polishing rice for the market removes these layers. A diet restricted to polished rice will not sustain health or life. Funk found that animals suffering from the effects of such a deficiency are immediately benefited and restored to health if rice polishings are added to their food. This same vitamin was found in other sources, notably yeast.

Professor Hopkins announced in 1912 the results of convincing experiments in which he showed that young rats fed on a "synthetic" diet of pure protein, carbohydrate, fat (lard), and mineral salts lost weight and showed symptoms of serious disease. A second group of young rats were given the same food with the addition of a very small amount of fresh milk. This group of rats flourished and grew normally. After eighteen days the diets were reversed so that the second group lost its fresh milk and the first received an addition of the same minute amount of fresh milk that had been given the other group. The first group then began to

gain in weight and health. The second soon began to lose weight and showed symptoms of distress. The amount of milk used was very small—about two five-hundredths of a pint in twenty-four hours. There was something in the milk that was essential to health and to life—something that was not protein, fat, carbohydrate, or inorganic salt.

These results of Hopkins were soon verified by numerous investigators. In 1915 McCollum described two vitamins which he called Fat-Soluble A and Water-Soluble B; Vitamin A is soluble in fat, Vitamin B in water. Vitamin A is the factor with which Hopkins was dealing in his experiments on rats. Vitamin B is the factor with which Funk was dealing in his experiments on polished and unpolished rice. More recently, the existence of a third vitamin known as Water-Soluble C has been proved. A number of additional vitamins have been announced. Two of them, Vitamins D and E, are accepted.

Vitamins A, B, C, and D are essential to growth in the period of infancy and childhood. They are essential to the maintenance of health and life in all age periods. They are not related one to the other. No one of them will take the place of any of the others.

We do not understand the action of these mysterious and essential substances. The part they play in the physiology of the tissue cell is yet to be discovered. But there is no question as to their influence on growth, on the maintenance of health, and on life itself.

It is evident that scientific investigators have produced convincing proof in recent years that there are several—at least five—remarkable and hitherto unknown substances essential to health and to life hidden mysteriously in various foods. (1) Vitamin A is the fat-soluble, growth-producing factor found in leafy vegetables, whole milk, cream, and butter. It is essential to growth. (2) Vitamin B is the water-soluble antineuritic vitamin occurring in varying amounts in nearly all foodstuffs, but principally in the eggs of animals and the seeds of plants. It is a growth-producing factor. Its absence produces a disease known as beriberi and may have something to do with pellagra, a common disease in southern United States. (3) Vitamin C, the antiscorbutic vitamin, is found chiefly in fruits and leafy vegetables. Its absence produces scurvy (scorbutus). (4) Vitamin D is the antirachitic vitamin occurring abundantly in cod liver oil and in egg

yolk. It is "concerned chiefly in regulating the concentrations of phosphorus and calcium in the blood and in controlling the process of calcification in the bones and teeth" (Howell). (5) Vitamin E is the antisterility vitamin. It is found in green leaves and cereals. Its absence produces sterility[1] in rats. Its relation to sterility in man is not known. Other vitamins have been announced.

It is obvious from the lists of sources of vitamins given above that in normal times vitamin deficiencies are not likely to occur except with infants and under conditions of extreme poverty. "If the daily diet contains milk, cereals, potato, green vegetables, and some fruit, one need not fear a vitamine deficiency" (Holt).

There is no occasion for the normal individual to be specially concerned about his vitamin supply. Commercial exploitation of vitamins serves no useful or important purpose. The daily mixed diet supplied in all American homes contains ample amounts of all of the known vitamins. These facts do not apply to certain Oriental countries in which very restricted dietaries are characteristic. They do not apply under the extremes of war, famine, and other calamities that interfere profoundly with the food supply of a people. They do not apply to infants and to other dependents of similar helplessness.

Flavors and condiments.—Certain further accessory articles of diet of more or less value as food need to be listed and briefly discussed.[2] The additions we make to foods to season them and give them palatable flavors and savory fragrances are, with some exceptions, of little value as foods. These flavors and condiments are of very real value, however, in the attractiveness to taste and smell which they furnish to food. The sight of attractive food, the smell of fragrant food, and the taste of agreeable flavors on foods are physiological influences that tease the appetite and stimulate the flow of digestive juices and thus favor normal digestion. The condiments and flavors have been classified thus: (*a*) aromatics—vanilla, anise, cinnamon, nutmeg, and other similar products; (*b*) peppers; (*c*) alliaceous condiments—garlic, mustard, etc.; (*d*) acid condiments—vinegar, citron, pickles, etc.; (*e*) salty condiments, such as table salt; (*f*) sugar condiments (Gautier).

[1] Howell, *op. cit.*, pp. 928–34.

[2] The statements in this section are taken largely from the seventh edition of Howell's *Textbook of Physiology*.

Stimulants.—Another group of dietary accessories characterized by their stimulating influences includes meat extracts (beef tea, etc.), chocolate, cocoa, coffee, tea, and alcohol. (*a*) The meat extracts contain very little food. They stimulate the glands of the stomach to secrete digestive juices and are therefore useful in recovery from disease, fatigue, debility, etc. (*b*) Coffee and tea stimulate the nerve centers, and thus increase blood pressure, augment muscular activity, and diminish the sense of fatigue. Coffee and tea have no important food values other than those in their water, inorganic salts, and the sugar and milk that go with them. (*c*) Cocoa and chocolate are mild nerve-center stimulants. They contain also considerable nourishment especially when served with sugar and cream. Their fluid and inorganic salt constituency is important. (*d*) Alcohol in excess seriously endangers health. A discussion of alcohol as an agent that injures health belongs to another division of hygiene and is considered in Part II of this volume. A great deal has been written and many conflicting statements have been made concerning the health relations of alcohol taken in moderate amounts. The value of alcohol as a stimulant is uncertain. Experimental data conflict as to its mental and nervous effects. It increases the watery content of the gastric and pancreatic secretions but does not seem to increase the digestive ferments in those secretions. Alcohol has no direct effect on the heart and blood vessels. Indirectly, it quickens the pulse, dilates the blood vessels of the skin, and stimulates the respiratory center. It is of little value to the neuro-muscular mechanisms and cannot be said, therefore, to serve a useful purpose in promoting muscular activity. It may remove the feeling of faintness that comes at times after an accident or an experience of emergency excitement. It may remove the feeling of depression, and it may overcome the feeling of fatigue that arrives at the end of the day.

The weight of evidence indicates that alcohol in moderation acts as a true foodstuff, though it is practical as a food only in sickness. Its use is always unsafe. The conclusion that alcohol may serve as a true foodstuff is based on the following scientific evidence: (1) alcohol is oxidized by the tissue cells; (2) it may be used by the cells in place of other carbon-containing foodstuffs; (3) if an alcohol diet is maintained, the initial injurious effect on protein metabolism disappears after a few days and the body ceases to lose its protein tissue and may even lay up protein.

Preparation of foodstuffs for the tissue cell.—The chemical substances necessary to the structure and function of the human tissue cell must undergo many rearrangements as constituent parts of foodstuffs on their way from the soil and the air to the living human cell. Oxygen is the only chemical element that is taken into the body directly and not in combination with some other chemical.

Preparation by plants.—With the exception of the oxygen of respiration, and the chemicals present in drinking water, all the chemical requirements of the tissue cell are first assembled from the air and the soil by plants through their leaves and their roots. These chemicals are rearranged by the analytic and synthetic chemistry of the tissue cells of the plant and are thereby made a part of the plant. Certain plants are used directly by man for food. Other plants serve as food for other animals than man. All the animal foods consumed by human beings are from animals that live directly or indirectly on plants. It may be said, therefore, that the proteins, fats, and carbohydrates, the inorganic salts, and the vitamins necessary to the life of the human tissue cell are manufactured and assembled into foodstuffs originally by plant cells out of chemical substances secured by plants through their leaves from the air and through their roots from the soil. A part of the vegetable kingdom is engaged in preparing foodstuffs directly and indirectly for the human tissue cell.

Preparation by animals.—A number of the most important of our foodstuffs are animal foodstuffs such as meat, eggs, and milk and milk products. These foodstuffs are products of the chemistry of the animal tissue cell and are built up (synthesized) from the proteins, fats, carbohydrates, salts, and vitamins present in the plant foods of those animals. It is evident that a part of the animal kingdom is engaged in preparing foodstuffs for the human tissue cell.

Preparation for market.—With the increase that has come in the population of the earth and with the growth of great centers of urban population, the preparation of vegetable and animal foodstuffs for human consumption has become a very complicated and varied sequence of procedures. This preparation involves problems of quantity and quality production, problems of safeguarded transportation to many and distant markets, and problems of rapid and frequent distribution to the consumer. Rural

life is giving way to city life and it is no longer possible to depend upon natural forces and influences for an adequate supply of foodstuffs. The production, transportation, and distribution of foodstuffs has become a world service and a world problem. The vital needs of the human tissue cells in any one part of the world are more or less completely dependent upon the rest of the world for the satisfaction of their food requirements.

Domestic preparation.—But after wheat has been produced in Argentina, Russia, or California, milled in Chicago, New Orleans, or Minneapolis, shipped as flour to market anywhere in the world, and distributed to the ultimate consumer, there is yet much to be done before its food content reaches the human tissue cell. The same may be said of the products of the stock ranges of Texas, or Wyoming, the fisheries of Alaska, Washington, or the Grand Banks, or the dairy farms of Oregon. After all the complications of production, packing, transportation, marketing, and distribution, there is still much more to be done before the food is ready for the table and before the foodstuff is ready for the tissue cell.

Successful preparation for the consumer in the home, the restaurant, or the delicatessen shop means a preparation of food that makes it attractive to the eye, to the sense of smell, and to taste. And, too, good preparation means a preparation of food that makes digestion easier. This applies particularly to cooking. In this same connection it may be insisted that attractive table appointments and habits have a real relationship to good digestion and, therefore, to the preparation of food for the consumer.

Physiological preparation of foods.—But, important as the commercial and domestic preparations are, they are important only in so far as they serve useful ends in relation to the later physiological preparation of the eaten food for the purposes of the tissue cell. This preparation begins as soon as the food enters the mouth and is accomplished as a result of various physiological influences that are brought to bear on the food in sequence in the mouth, the stomach, the intestines, the intestinal walls, the liver, the circulation, the lymph spaces about the tissue cells, and the tissue cells themselves. These sequences of cause and effect constitute a fundamentally important part of physiology and of hygiene. They are basic to a rational understanding of constructive hygiene as well as of defensive hygiene.

It is a long way from the carbon, hydrogen, oxygen, and nitrogen of the air and the carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur, iron, and inorganic salts of the soil to the living grasses, grains, vegetables, and fruits of the field, the garden, and the orchard. And it is another far cry to the buttered toast, the soft-boiled eggs, the broiled steak, and the glass of milk that may be found on the breakfast table. But it is an even more lengthy and remarkable journey that brings these chemicals to and makes them parts of the living human tissue cell. The lightning of the cloud and the bacterium of the soil that bring the nitrogen of the air into a chemical combination which the plant may build into vegetable protein initiate a preparation of foodstuffs that, after a long and devious journey, may be built into human muscle, nerve, and sinew. The chlorophyll of the green leaf, with the aid of sunlight and sun-heat, takes carbon from the carbon dioxide of the air, and, out of carbon from the air and hydrogen and oxygen from the soil, the plant builds carbohydrate foodstuffs that, after a long series of experiences, may furnish the nervous energy out of which human thought, human memory, or human sensibilities are made or the muscular energy that earns a day's wages, sings the prologue from *Pagliacci,* or wins a football game.

The great variety of foods that come from the farm, the stock range, the orchard, the garden, the dairy, the fisheries, that pass through the mills, the meat packeries, the fruit packeries, and the canneries, and that reach the consumer by way of the grocer, the butcher, the baker, the fruiterer, the creamery, the milkman, and the delicatessen store are all preparations of protein, fat, and carbohydrate foodstuffs with varying proportions of inorganic salts and water and with minute traces of vitamins A, B, and C.

The preparation in the kitchen and the service in the dining-room of the home, the restaurant, or the hotel is, as has been stated above, for the stimulation of the appetite and for the encouragement of digestion. The digestive processes in the human alimentary canal constitute the real preparation of these foodstuffs and their accessories for the living tissue cell.

In order to reach every one of the millions of millions of hungry tissue cells, the eaten food must be so prepared in the alimentary canal and so distributed by the blood and lymph that it will be evenly and minutely and properly apportioned to these

microscopic ultimate consumers. They cannot be fed with solid food. They must not be fed with food that is lacking in any important chemical. The protein, fat, and carbohydrate molecules that build the plants and that build other animals than man cannot be used without change to build the human tissues and organs.

And so the purpose of human digestion is to break up the eaten food into fine particles, to dissolve those parts to a consistency of soup, to break up the complex molecules of protein, fat, and carbohydrate compounds into simple chemical compounds, to change those compounds so that they will be absorbed easily through the walls of the intestines and be then available in the blood stream in a chemical form which the tissue cells may use for purposes of construction, repair, manufacture, and service.

Psychic secretions.—When mealtime arrives, a good appetite and the anticipation of food will stimulate a secretion of saliva in the mouth and of gastric juice in the stomach. The fragrance of cooking and the sight of attractive food also combine to start a flow of saliva and of gastric juice. Such secretions are called psychic secretions. They might be called enjoyment secretions.

Nervous secretions.—As soon as palatable food is placed in the mouth, its pleasing taste causes a secretion of saliva and of gastric fluid. Secretions under these circumstances are due to nervous impulses that travel from the taste organ on the tongue to a nerve center in the lower brain (the medulla), from which reflex nervous impulses are sent to the salivary glands and gastric glands, stimulating them to secrete. Such secretions are called nervous secretions. (See Fig. 38, p. 159, illustrating gland-cells.)

The thought of food, the anticipation of food, and the sight, smell, and taste of food combine through psychical and nervous stimulation to start a secretion of digestive juices in the mouth and in the stomach in preparation for the digestion of food.

Chemical secretions.—The digestive secretions of the stomach are stimulated on the arrival of certain foods in the stomach. Meat extracts, meat juices, soups, alcohol in small amounts, contain some substance or substances that are absorbed into the blood of the stomach wall, are carried by the blood to the gastric glands, and stimulate them to secrete. Those substances are called secretogogues. In addition, the products of digestion in the stomach (gastric digestion) contain similar substances. Milk and water on reaching the stomach cause but little secretion. Bread

and the white of eggs have no secretory effect. Something contained in the normal secretions of the stomach on being absorbed into the blood in the stomach walls is carried to the digestive glands of the stomach and causes those glands to secrete digestive fluids. This is an example of hormone action. When one organ secretes a substance that causes another organ to become active when carried to that organ by the blood, the substance is called a hormone.

We have, then, in the digestive tract, psychical secretions, nervous secretions, and chemical secretions. Chemical secretions may be caused by secretogogues in food, by secretogogues produced by the digestion of foods, and by hormones.

When the food passes from the stomach into the small intestine nervous and chemical secretions occur for the purposes of digestion. These secretions are present throughout the length of the small intestine. They come from the pancreas, the liver (the bile), and from glands in the walls of the small intestine.

On passing from the small intestine into the large intestine, the digesting food carries with it the digestive substances that have been added in the small intestine. Under normal conditions digestive activity may continue for some hours in the large intestine. No digestive fluids are secreted from the walls of the large intestine. (See Figs. 39, 40, and 41, pp. 162, 165, and 167, for description of alimentary canal.)

Foods and secretions in the alimentary canal.—The movements of the mouth, the gullet (esophagus), the stomach, and the small intestine have been carefully studied. Dr. Walter B. Cannon, professor of physiology at Harvard, has added a great deal to our knowledge of the nature and significance of these movements. From these researches we know that the movements of the alimentary canal are for the purpose of breaking up the food in the canal into small particles and mixing those particles thoroughly with the digestive fluids of the canal. This breaking up and mixing process facilitates digestion. In addition, these movements serve to bring all parts of the soupy products of digestion into contact with the walls of the intestine so that absorption of those products through the walls is made easier. Finally, certain of these movements are propulsive. That is to say, in addition to the churning and mixing movements of the muscles in the canal walls, there are other movements that push the contents onward so

that the entire length of the small and large intestine is traversed by the food in the process of digestion. The indigestible parts and undigested parts of food, and secretory and other débris from the walls of the canal are finally ejected from the rectal end of the alimentary canal as feces.

Digestion of food.—After becoming thoroughly broken up and mixed with the secretions of the alimentary canal (first, with the secretions that are emptied into the mouth; second, with those that are emptied into the stomach; and third, with those that are emptied into the small intestine), the contents of the soupy mixtures are much changed chemically. The complex protein molecules, the carbohydrate molecules, and the fat molecules are broken up and decomposed into simpler chemical bodies. This is the end-purpose of digestion.

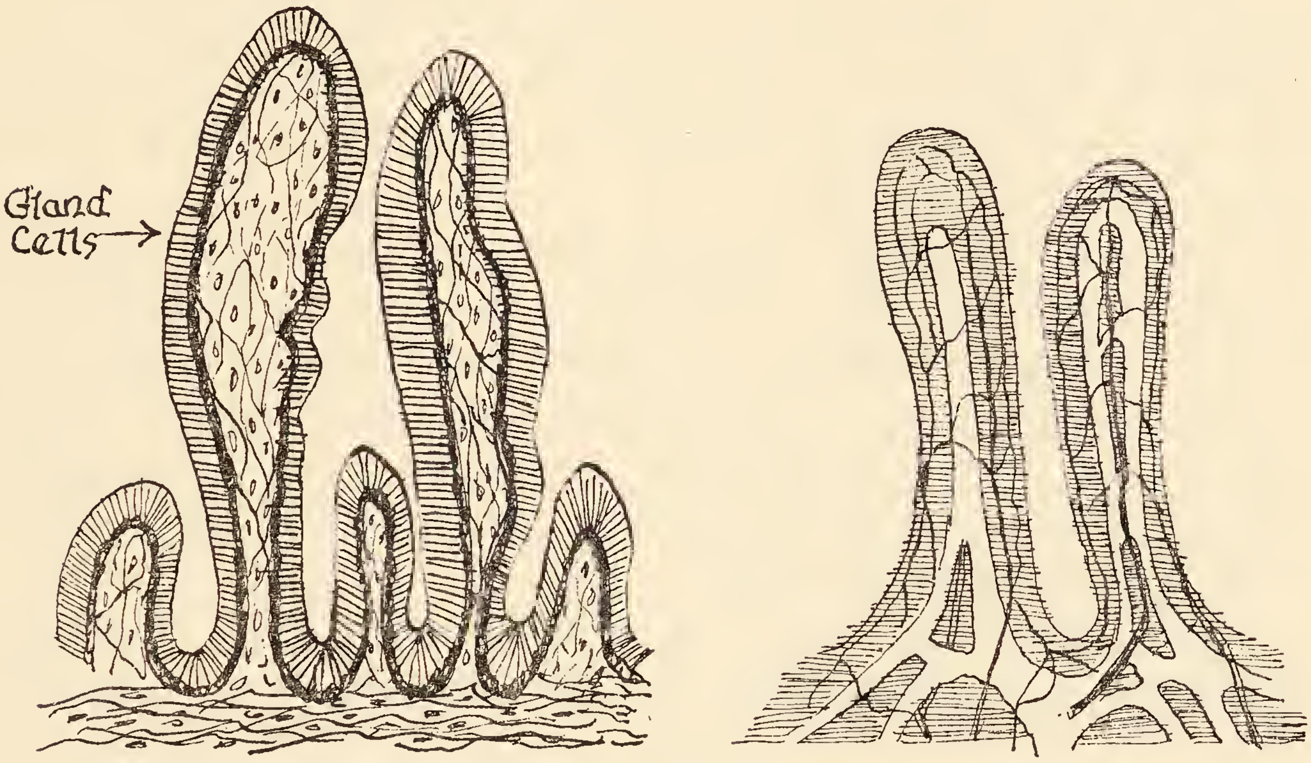
Enzymes.—The result is accomplished by the action of enzymes (or ferments). The digestive secretions contain a number of enzymes. Some of them act on the carbohydrates, converting starch to sugar, or converting a more complex sugar into a simple sugar. Other enzymes act on the proteins, decomposing them into their simpler amino-acids. And finally, there is an enzyme in the digestive tract that splits neutral fats into fatty acids and glycerin.

The simple sugar dextrose (another name for glucose), the amino-acids, and the fatty acids and glycerin are the simpler chemical bodies produced by the digestive action of enzymes that may be absorbed from the intestine into the blood and lymph in the intestinal walls and carried by those circulating fluids to the tissue cells for which those simpler chemical bodies have been so specially and so carefully prepared.

We do not know the chemical structure of enzymes. We do not know how they are made. We do know that they are made by tissue cells out of chemical substance brought by the blood. Each enzyme is specific. That is to say, the enzyme that splits up the protein molecule will not affect the carbohydrate or fat molecule; the enzyme that changes starch to sugar will not convert fat to fatty acids and glycerin; the fat-splitting enzyme has no influence on carbohydrates or proteins.

The most remarkable thing about the enzymes of the alimentary canal (and all other enzymes, for that matter) is that they produce these profound changes upon foodstuffs without themselves undergoing chemical change. Their influence is pow-

erful even though they are present only in minute quantity, and they accomplish their influence by their mere presence or by their mere contact. This action is what the chemist calls catalysis. The enzymes do not enter into chemical combination with the substances that they decompose. Their relationship is merely a physical association. When a protein, fat, or carbohydrate molecule is in the presence of water, the mere contact with an appropriate enzyme will produce a decomposition, or cleavage of the protein, fat, or carbohydrate molecule. This decomposition or cleavage by reaction with water is called hydrolysis. The enzymes of the alimentary canal act by hydrolysis. The chemist would say that they are catalizers that act by hydrolysis.



A B

FIG. 38.—Villi, much enlarged, from human intestine: *A,* showing gland-cells; *B,* showing lacteal vessels in clear white channels, with blood vessels and their capillaries shown in black lines.

Absorption of digested foods.—After the digestive fluids in the stomach and the small intestine have performed their work, it is necessary that the fluid products of digestion be absorbed into the blood for distribution to the tissue cells. We find that absorption proceeds with effectiveness in the small and large intestines. Under certain circumstances, absorption may take place from the mouth and the stomach, but absorption in these places is not needed for the purposes of nutrition. Digestion has hardly begun

while the food is in the mouth and has not gone very far while it is in the stomach. From the point of view of digestion, there is no occasion for absorption from the mouth or the stomach.

The products of protein and carbohydrate digestion are absorbed directly into the blood capillaries of the minute villi that project from the inner walls of the small intestine. The products of the digestion of fats are absorbed into the lacteals (lymph capillaries) in the villi. (See Fig. 38.)

The absorption of the products of digestion in the alimentary canal is not a mere matter of imbibition, osmosis, and diffusion. The simple sugars, amino-acids, fatty acids, glycerin, water, and inorganic salts that pass from the lumen of the canal directly into the blood capillaries, or indirectly into the blood stream by way of the lacteals, seem to be drawn out of the canal because of an additional functional energy in the cells of the walls of the intestine. If there is such an energy it is probably furnished by the epithelial cells of the villi.

We have discussed the general physiological preparation of foodstuffs for the tissue cell, stating the general significance of the secretions, movements, enzymes, and absorption that characterize the alimentary canal. A brief consideration of the special functions of the mouth, stomach, small intestine, and large intestine will serve to make more clear the important facts in this phase of constructive hygiene.

Preparation in the mouth.—The mouth is the beginning of the alimentary canal. The entire canal is from thirty to forty feet long. From the point of view of digestion, the service of the mouth is preparatory to events that take place farther along in the canal.

The habit of reasonably deliberate and reasonably thorough chewing accomplishes several important results. Reference has already been made to the psychical and nervous secretions of saliva and of gastric juice. They are encouraged by chewing. Thorough and deliberate chewing breaks up and moistens dry food so that it may be tasted. The stimulation of salivary and gastric secretions is thus reinforced. Such chewing brings the enzymes of the saliva into intimate contact with all the food particles. There are two of these enzymes in saliva. One of them, ptyalin, changes starch to sugar (maltose). The other, maltase, changes maltose to a simple sugar called dextrose (commonly

known as glucose). There are no enzymes in the mouth for the digestion of proteins or fats. Chewing moistens and lubricates the food so that it may be more easily swallowed—dry food cannot be swallowed.

Food is not retained long enough in the mouth to give much opportunity for carbohydrate (starch and sugar) digestion. However, the salivary ferments may act for an hour or more after the food reaches the stomach. There is hardly time for absorption from the mouth.

The habit of chewing food slowly, combined with the necessity of swallowing food piecemeal, insures a slow delivery of small installments of food into the stomach.

Preparation in the stomach.—Food is swallowed into the stomach faster than it can pass through the stomach. Semi-solid and solid foods are, therefore, stored in the upper or cardiac end or fundus of the stomach until they can be acted upon by the gastric secretions in the lower mixing part or pyloric end of the stomach. Liquids are allowed to pass through the stomach in a sort of canal or by-pass between the mass of stored food and the stomach wall directly from the entrance of the gullet into the stomach to the exit from the stomach into the small intestine. This exit is called the pylorus. It might be said, then, that liquids tunnel their way by the food in the upper portion of the stomach along the stomach wall from the gullet to the lower portion of the stomach. The stomach wall along this line of nearest distance between these two points obligingly wrinkles its surface into an accommodating canal for the purpose.

The interior of the stomach must not be thought of as an empty cavity at any time. Whatever "cavity" there may be is always as large as the contents of the stomach. Immediately after a meal the upper end or fundus of the stomach is packed with solid and semi-solid food under pressure from the surrounding muscular walls of the stomach; the middle and lower surfaces of the stomach are secreting digestive fluids and surround the food that has been forced down from the fundus; the lower part of the stomach contains fluid material made up of fluids that have been swallowed and those that were secreted by the glands of the stomach; and the muscles in the lower part of the stomach walls from the mid-region to the pylorus are engaged in an orderly sequence of contractions and relaxations. These contractions

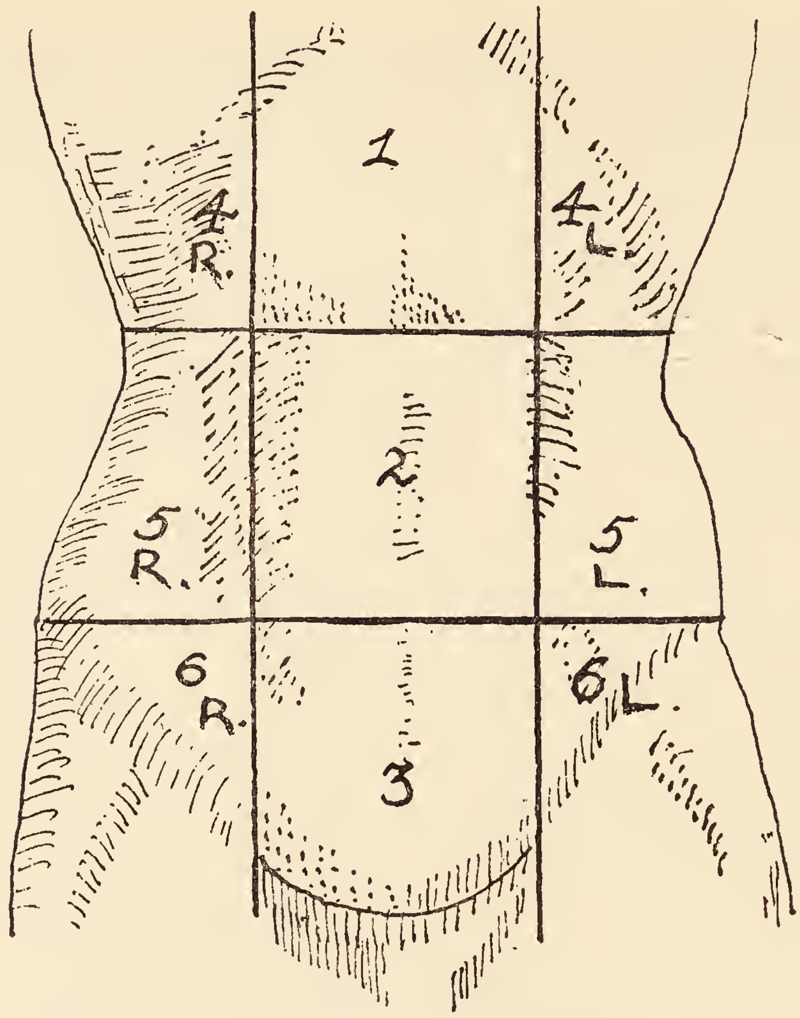


FIG. 39.—Outline of the regions occupied by various organs in the abdomen.

1. Epigastric region. This region contains a large part of the liver, the gall-bladder, part of the stomach, including the entrance from the esophagus (gullet) and the opening (pylorus) into the duodenum (upper part of the small intestine), part of the duodenum, the pancreas, part of the spleen, part of each kidney, and both suprarenal bodies.

2. Umbilical region. Contains most of the transverse colon (part of the large intestine), a part of the duodenum, part of the small intestine, part of the right kidney, sometimes parts of both kidneys.

3. Hypogastric region. Contains part of the small intestine, the bladder in childhood and in adults when full, the uterus during pregnancy, part of the descending colon, and the upper part of the rectum.

4*R*. Right hypochondriac region. Contains part of the right lobe of the liver, the end of the ascending and the beginning of the transverse colon (the hepatic flexure), and part of the right kidney.

4*L*. Left hypochondriac region. Contains part of the stomach, most of the spleen, a small part of the pancreas, the end of the transverse and the beginning of the descending colon (the splenic flexure), and occasionally part of the left lobe of the liver.

5*R*. Right lumbar region. Contains the ascending colon, part of the right kidney, and sometimes part of the small intestine.

5*L*. Left lumbar region. Contains the descending colon, part of the small intestine, and occasionally part of the left kidney.

6*R*. Right iliac region. Contains the entrance of the small intestine into the large intestine; and also the vermiform appendix.

6*L*. Left iliac region. Contains part of the descending colon and part of the small intestine. (After Thane and Godlee, *Quain's Anatomy,* Longmans. Green & Co., 1896, Appendix, p. 23.)

break up the food that has been pushed from the fundus into the lower part of the stomach. They insure a thorough mixing with the digestive fluids of the stomach.

The carbohydrate enzymes furnished by the glands of the mouth continue their digestive action in the fundus of the stomach during the time the food is stored there. This may continue for an hour or more. There are no carbohydrate enzymes furnished by the stomach and no enzymes for the digestion of fats.

The glands of the stomach produce several secretions that are concerned with the digestion of protein food. Pepsin is the enzyme that digests proteins in the stomach. Pepsin will not act in other than an acid medium. Certain cells of the stomach walls secrete hydrochloric acid. This acid provides the acid medium necessary for the action of pepsin. Other cells of the gastric walls secrete rennin, an enzyme that curdles milk. Rennin does not digest milk. Its only action is to curdle milk, thus getting it ready for the digestive action of pepsin. Certain of the gland cells of the stomach produce secretogogues and hormones, to which reference has already been made.

For a period of two or three hours after a full meal, digestive activities continue in the stomach. The food stored in the fundus is slowly forced into the lower part of the stomach, mixed there with digestive fluids, and made into a consistency of pea soup. The fluid products of gastric digestion as they appear in the pyloric end of the stomach are called chyme. The stomach is separated from the small intestine by a muscular valve called the pylorus. At intervals during gastric digestion the pylorus opens, connecting the stomach with the duodenum, or upper end of the small intestine. When the pylorus opens during gastric digestion small amounts of chyme are forced through the opening into the duodenum. The pylorus will not open when solid pieces of food are forced against it. The pylorus will not open while the fluid contents of that part of the stomach are alkaline in reaction. After the lower stomach contents are made acid by the hydrochloric acid secreted by the parietal gastric glands and after the lower stomach contents have been broken up and digested into the fluid consistency of chyme, the pylorus opens and discharges chyme into the duodenum. Almost immediately, the pylorus closes again. This closure is due to the fact that the pylorus likewise will not open while the contents of the duodenum are acid. The secretions that

pour into the duodenum from the pancreas, the liver, and the other glands are alkaline. During digestion the contents of the lower stomach become acid and those of the duodenum alkaline. The pylorus opens, a small amount of acid chyme is forced into the duodenum and a small amount of alkaline fluid from the duodenum regurgitates into the lower stomach. The pyloric gate immediately closes in response to the acid chyme in the duodenum and the alkaline return in the lower end of the stomach. By this arrangement there is secured a slow delivery into the small intestine (duodenum) of food specially prepared by the stomach. Good digestion is a leisurely and deliberate series of procedures. Unhurried mastication, insalivation, and swallowing prepare and deliver food to the stomach in accord with the time requirements of that organ for the more satisfactory accomplishment of its digestive functions. The remarkable mechanisms that govern the opening and closing of the pylorus provide a slow, "piecemeal" delivery into the small intestine of food that has been specially prepared by the stomach for digestion in the small intestine.

The digestion of no foodstuff is completed in the mouth or stomach. The fats are probably not affected other than that they are melted by the body heat and liberated from their physical association with other foods and churned into a fine emulsion. The carbohydrates are partly digested by the enzyme ptyalin while the recently swallowed food is stored temporarily in the fundus of the stomach. The proteins are partially digested by the enzyme pepsin (with the assistance of hydrochloric acid and, when milk is to be digested, rennin). Water is passed on to the small intestine. The salts are probably not absorbed in the stomach. They are passed on to the small intestine. The digestive history of the vitamins is not known.

Preparation in the small intestine.—The most important of the physiological processes in the digestive preparation of food for the tissue cell takes place in the small intestine. This part of the alimentary canal is from twenty-five to thirty feet in length. Its upper end, continuing from the stomach, is called the duodenum. The lower end continues into the large intestine by the ileo-cecal valve. The duodenum is only a few inches in length. The lumen of the small intestine is from one to two inches in diameter.

Various ingredients of the chyme on entering the duodenum

cause a nervous and a chemical secretion from the pancreas and from the liver (bile). Certain small glands in the walls of the small intestine then become active. Some of these glands empty their secretions into the lumen of the intestine. These glands that empty into the canal are at present thought to be relatively unimportant. Other small glands in the walls do not empty their secretions into the small intestine. They produce enzymes that act upon the products of previous digestion while those products are in the process of absorption in the intestinal walls. These digestive glands in the walls of the small intestine are very important.

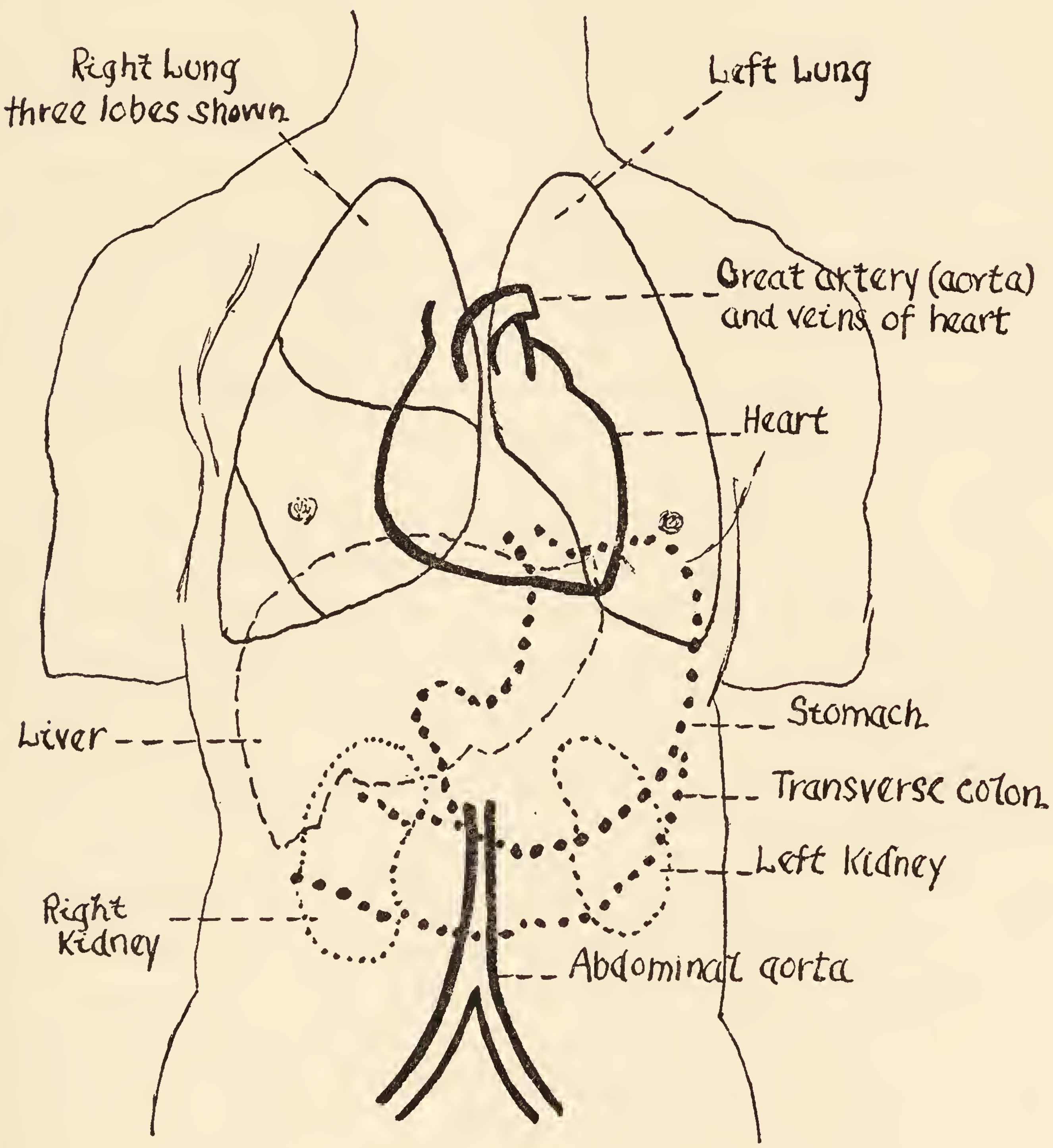


FIG. 40.—View of trunk (thorax and abdomen) from the front, showing the principal organs contained in outline. (Modified from Godlee and Thane, *Quain's Anatomy,* Longmans, Green & Co., 1896, Appendix, p. 21.)

The walls of the small intestine are largely formed of muscle-tissues. The orderly, co-ordinated contractions and relaxations of these muscles act on the food particles throughout the length of the small intestine, separating them and combining them continuously during the period of intestinal digestion, mixing them intimately and thoroughly with the fluids that are present. In addition, these movements bring all parts of the fluid contents into a contact relationship with the inner surface of the intestine, thus assisting in the absorption of the products of digestion. Finally, certain of these movements push the intestinal contents onward through the ileo-cecal valve into the large intestine.

The enzymes of the pancreas digest proteins, fats, and carbohydrates. The bile is not an enzyme, but its emulsifying action assists the fat-splitting enzyme of the pancreas. The enzymes of the pancreas concerned in the processes of digestion are known as: (1) trypsin, a protein enzyme; (2) amylase, an enzyme that changes starch to sugar (maltose); (3) lipase, an enzyme that splits neutral fats into fatty acids and glycerin. The enzyme lipase is the only one of these three agents that completes the preparation of a foodstuff for the tissue cell. The fatty acids and glycerin are produced by the interaction of water and fats in the presence of lipase and are absorbed as such.

The enzymes that are produced by glands in the walls of the small intestine and perform their physiological activities within those walls complete the preparation of proteins and carbohydrates for the tissue cells. Invertase, maltase, and lactase are enzymes in the intestinal walls that bring about the final changes necessary for the preparation of sugar for the tissue cell or for transportation to the liver, where the excess of sugar in the blood is changed into glycogen and stored by the liver-cells until it is needed by tissue cells elsewhere. The final product of this carbohydrate digestion is chiefly dextrose and, probably, levulose and galactose. Finally, an enzyme called erepsin is secreted in the walls of the small intestine. It splits peptones and proteoses (the products of the action of pepsin and trypsin) into their constituent amino-acids. There are twenty amino-acids now known. They are the simpler compounds containing nitrogen. They are produced by the digestion of protein. They are in a form that may be absorbed by the tissue cell.

Preparation of oxygen.—All the chemical substances neces-

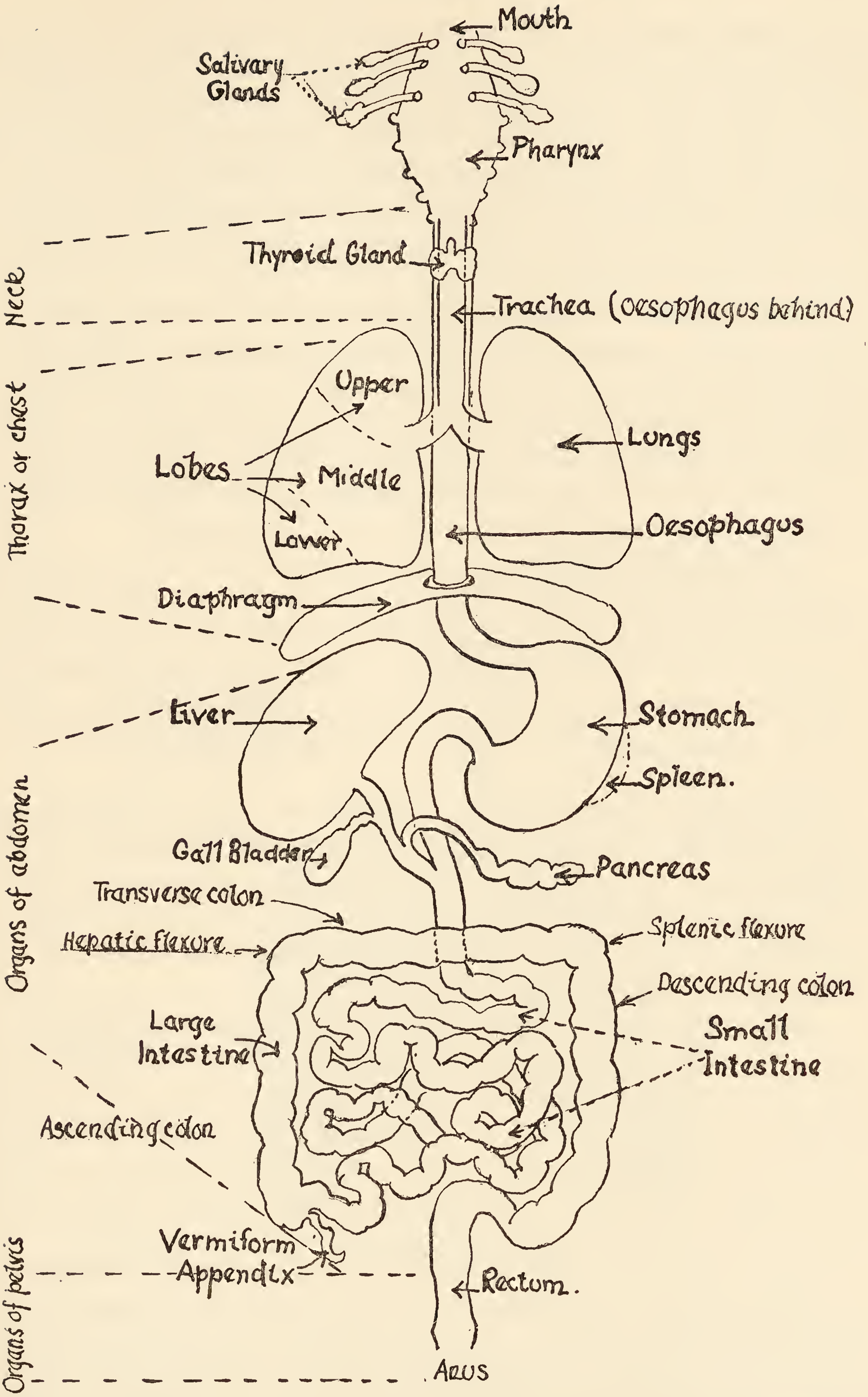


FIG. 41.—General plan of the human alimentary canal. (Modification from L. L. Woodruff, *Foundations of Biology,* The Macmillan Co., 1924, p. 155.)

sary to the nutrition and health of the human tissue cell, with the exception of the respired oxygen, are supplied in chemical combination with other elements. And all the chemical intake of the human body, except free oxygen, is supplied by way of the alimentary canal. Free oxygen (that is, oxygen that is not in chemical combination) is absorbed from its physical mixture in the air by way of the lungs and distributed from the lungs to the tissue cells by the blood and lymph.

The objective features of respiration are the absorption of oxygen from a surrounding medium, air or water, and the consequent return discharge of carbon dioxide into the same medium. In accord with this description, respiration in some form or other exists in all plants and in all animals, with the possible exception of a comparatively few anerobic forms, notably certain bacteria, which seem to live only in the absence of free oxygen.

The simplest form of animal and plant life, the one-celled organism, absorbs oxygen through its single surface directly from the physical solution of oxygen in the air or water in which the organism lives. In these forms, carbon dioxide is discharged directly from the cell surface into the surrounding medium. The surface of the single cell of the one-celled organism is its respiratory apparatus.

The higher plants absorb oxygen from the air through the surfaces of their growing stems or through the surfaces of their smaller roots. Plant-roots and germinating seeds absorb free oxygen from the air in the soil in which they develop. Dense, packed soil or soil that is water-logged contains no air spaces and will, therefore, not sustain plant life.

The absorption of free oxygen by the higher animals is accomplished by more or less complicated forms of respiratory apparatus which bring air or water directly to the tissue cells through a system of tubes, as is the case with insects, or provide for an absorption of oxygen from water through gills or from air through lungs and a distribution of the absorbed oxygen to the tissue cells by way of the circulating blood. (See Fig. 42.)

Man and the other air-breathing vertebrates are provided with a respiratory apparatus that is characterized by an external respiration and an internal respiration. The external respiration is an exchange of gases (oxygen absorbed and carbon dioxide discharged) between the blood in the pulmonic capillaries in the

walls of the lungs and the air in the lung spaces. The internal respiration is an exchange of gases (oxygen and carbon dioxide) between the blood in the systemic capillaries and the tissue cells. By this arrangement free oxygen is absorbed from the inspired air in the lungs and carried by the arterial blood to the tissue cells. At the same time, carbon dioxide is absorbed from the tissue cells and carried by the venous blood to the lungs whence it is discharged in the expired air.

It is obvious that the essential feature of respiration is the absorption of oxygen through the cell wall into the cell protoplasm and the return discharge of carbon dioxide. The fact is evident in the case of the one-celled organism or the germinating plant seed. It is hidden somewhat by the complications of external respiration in the higher forms of life.

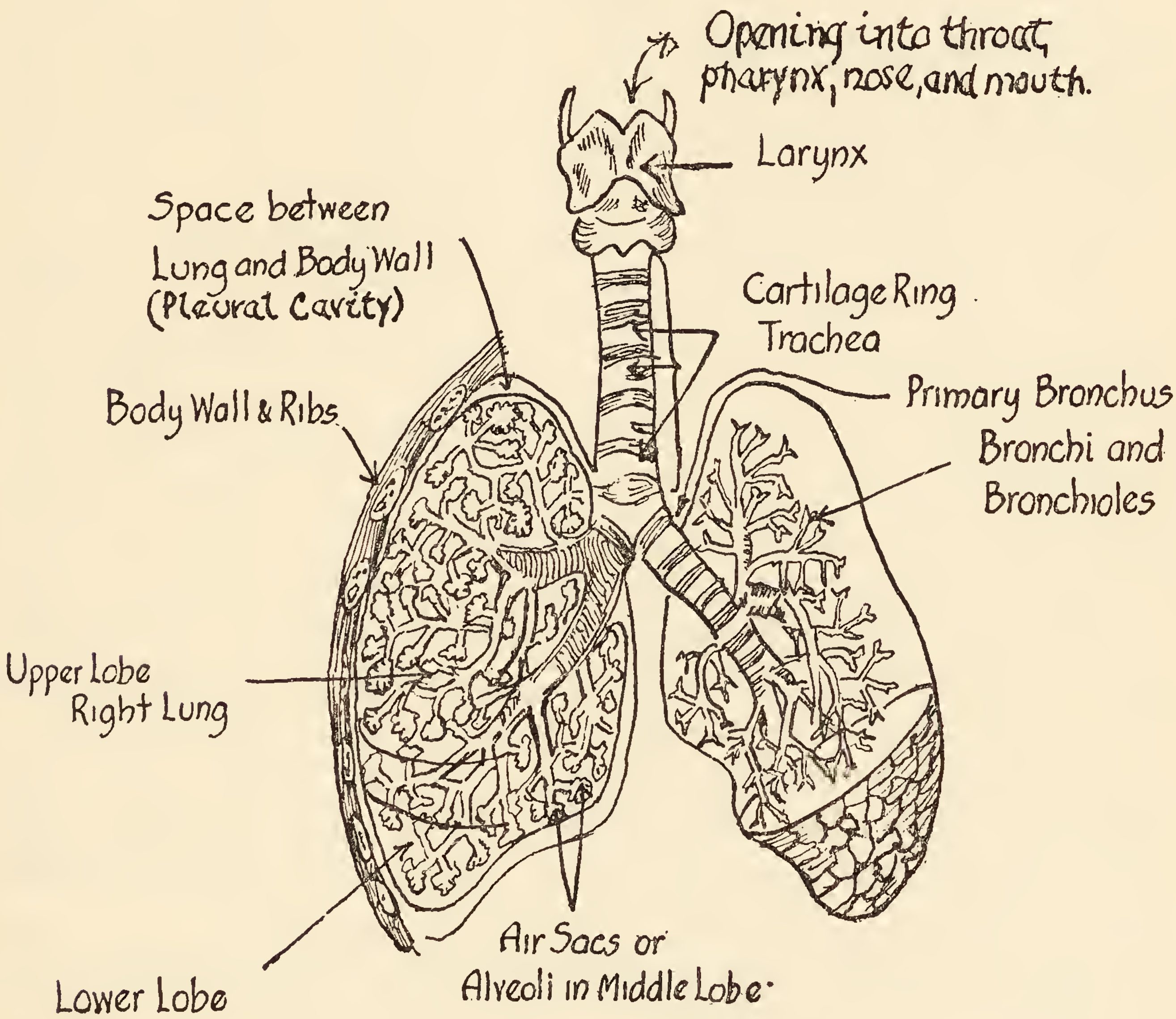


FIG. 42.—Outline of lower air-passages and lungs. The lobes of the right lung are represented in cross-section, showing the air sacs or alveoli. The left lung in part shows only the smaller divisions of the bronchi and the bronchioles. (Modified from C.-E. A. Winslow, *Healthy Living,* C. E. Merrill Co., 1920, p. 103.)

Foodstuffs in the blood.—We have seen that the chemicals of the air and the soil necessary to the health and life of the human tissue cell are finally absorbed into the blood on their way to the hungry cell. Free oxygen is absorbed directly from the air into the blood through the walls of the pulmonary capillaries in the lungs. This oxygen unites in a loose chemical compound with the hemoglobin of the red blood cells. The other chemicals reach the blood by a devious route involving, as has been pointed out: (1) absorption from the air by the leaves of plants and from the soil by the roots of plants and a synthesis (manufacture) into plant structure by plant cells; (2) absorption from the alimentary tract in food animals that live on plants and a synthesis into animal tissues by the animal cells (this is a complicated process more or less identical with that described for the human animal); and (3) absorption from the human alimentary canal of digested foods of plant and animal origin through the walls of the blood capillaries and lacteals (lymph capillaries) of the intestine. The lacteals empty their contents into the blood stream so that the foodstuffs all finally reach the circulating blood.

The essential chemicals that reach the blood in this manner are in the form of various chemical compounds. The carbohydrate molecule is present mainly as dextrose. Other names for dextrose are glucose and blood-sugar. The carbohydrate molecule, dextrose, is a compound of carbon, hydrogen, and oxygen. The fatty acids and glycerin absorbed by the intestine immediately unite and form droplets of fat that are carried by the lacteals to the thoracic duct and are there emptied as a fine emulsion into the great veins that go to the heart. The fats are compounds of carbon, hydrogen, and oxygen. The protein molecule reaches the blood in the form of amino-acid. The amino-acids are compounds of carbon, hydrogen, oxygen, and nitrogen, and sometimes sulphur or phosphorus. Water and inorganic salts reach the blood with no change in structure. They are absorbed without change into the blood and lymph capillaries of the small and large intestines. We do not know that anything happens to the vitamins in the digestion of food-plants or of food-animals. It is logical to suppose that they are originally products of the synthetic activities of plant cells and that they become available to animals because they are essential parts of the plants on which animals live. Since we have no knowledge of the chemical

structure of vitamins it is not possible to isolate them in the blood.

Normal blood, then, contains all the chemicals necessary to the nutrition of the tissue cell. These chemicals are compounds in forms that are available to the cell for manufacture (synthesis) by the cell into the living structure of the cell for growth or repair; or they are available for manufacture into the chemical substances with which the cell performs its special functions; or they are available as chemical bodies from which the cell derives its physiological energy.

The blood fluid, which is called serum, passes through the walls of the blood capillaries into the minute lymph spaces that surround the tissue cells. According to Professor August Krogh of Copenhagen there are as many as 2,000 blood capillaries in any field of one square millimeter of human striated muscle surface. "Supposing a man's muscles to weigh 50 kg. and his capillaries to number 2,000 per sq. mm., the total length of all these tubes put together must be something like 100,000 kilometers, or 2½ times around the globe, and their total surface 6,300 square meters."[1] Six thousand three hundred square meters represents about the area of a New York City block. It is obvious that the arrangements for the distribution of food to the tissue cells are remarkable in their microscopic perfection. (See Fig. 43.)

The fluid in the lymph spaces is called lymph. It has the same chemical content as the blood serum, and is the medium from which the tissue cell secures its chemical supplies—its nutrient requirements for growth, repair, energy, and service. And the lymph is also the medium into which the tissue cell discharges its extra-cellular secretions, its excretions, and its wastes.

Georgine Luden[2] calls attention to the remarkably small amounts of the various chemical essentials in the blood and the relatively small amounts of these chemicals in the body as a whole. The following is an extract from a comment on Luden's paper:

> . . . . The entire volume of circulating blood, which about half fills an ordinary bucket, contains only a small teaspoonful (from 4 to 6 gm.) of

[1] August Krogh, *The Anatomy and Physiology of Capillaries* (Yale University Press, 1929), p. 31.

[2] Georgine Luden, "The Importance of Visualizing Established Scientific Data with Reference to the Size of the Body Cells and Their Chemical Supplies in the Circulating Blood," *Endocrinology*, November 1921.

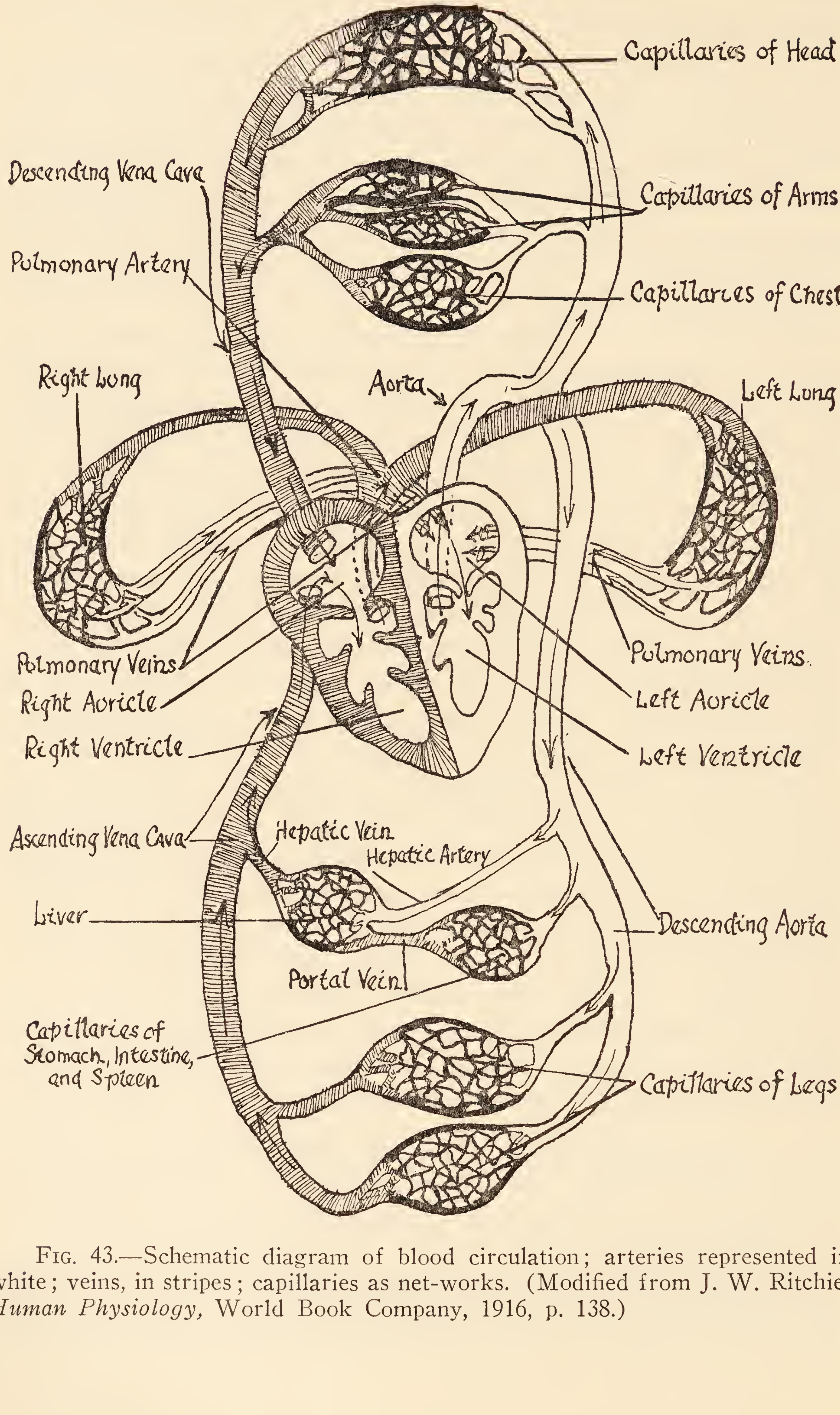


FIG. 43.—Schematic diagram of blood circulation; arteries represented in white; veins, in stripes; capillaries as net-works. (Modified from J. W. Ritchie, *Human Physiology,* World Book Company, 1916, p. 138.)

sugar and a tablespoonful (32 gm.) of salt. When we consider the minute variations in the sugar content that the modern chemist can measure in a few drops of blood, we gain added respect for the science of quantitative analysis. The iodin in the entire blood amounts to but 0.01 gm., or an average dose of atropin. When the physiologist tells us that epinephrin can be detected by biologic methods in a dilution of 1:330,000,000, it means far less than to say that it is equivalent to diluting "a small glass of whisky (10 c.c.)"—a very small glass, that—into the contents of 1,320 city street sprinkling-carts, which would form a procession about six miles long. We all know that the normal blood contains about 5,000,000 red corpuscles in each cubic millimeter, but do we all realize that the entire blood must therefore contain some 25 trillion (25,000,000,000,000) red cells and 30 billion leukocytes, figures that have an astronomical aspect? And do we realize that in all that mass of blood is distributed the insignificant quantity of from 1 to 3 grains (65 to 200 mg.) of uric acid, which we assay accurately and speculate about vaguely? Luden quotes an amusing, if not very precise, estimate of the total chemical composition of "the average man," which has recently been published by a big industrial company, and which may be thus summarized: fat enough for seven bars of soap; iron enough for a medium-sized nail; sugar enough to fill a shaker; lime enough to whitewash a chicken coop; phosphorus enough to make 2,200 match-tips; magnesium enough for a dose of magnesia; potassium enough to explode a toy cannon; and sulphur enough to rid a dog of fleas. Many items in this estimate are left largely to the imagination, such as the size of the dog and the number of his tormentors, but the total cost of the ingredients is given as 98 cents, which is neither expensive nor calculated to foster megalomania. The practical value of visualized scientific data lies not only in the stimulation of memory through the imagination, but also in the food for thought which they offer and in their bearing on great medical problems. If mental pictures of the billions and trillions of blood cells crowding, jostling, and possibly struggling for a share of the mere teaspoonful of sugar in the total blood volume of a full-sized man, or the endless procession of sprinkling-carts representing the epinephrin concentration to which animal tissues respond, appeal to one's sense of humor, they also do much more than this: They bring home the delicacy of the adjustment by which the human body mechanism is regulated; the extent to which this fine adjustment may be disturbed by seemingly trivial factors; the obligation of both laymen and physicians not to ignore the "slight" tokens of distress of the body engine; and the value of comparing the quantities used in the body chemistry with the "dosage" in therapeutics.[1]

Nutrition in the tissue cell.—The actual transformation of foodstuffs takes place in the living tissue cell. The human tissue cell is bathed in a fluid medium, the lymph. All the chemical needs of

[1] Editorial, *Journal of the American Medical Association,* May 6, 1922.

the cell are present in the fluid medium and are absorbed from that medium by the cell through its surface for its own vital purposes. All its non-living products, all its excretions and all its wastes are eventually discharged through its surface into this fluid medium. The exchange is influenced by the physical laws that govern the exchanges of gases and fluids when separated by an intervening permeable membrane. The protoplasm of the cell is a fluid or semi-fluid medium. The cell wall or cell surface is a permeable membrane. The surrounding film or stream of lymph is the second fluid. The absorption of nutrient compounds from the lymph through the cell wall into the cell protoplasm and the discharge of the products of cell activity from the protoplasm of the cell, through the wall of the cell into the lymph surrounding the cell, are events produced by diffusion, filtration, osmosis, and the vital energy of the cell.

The nutrition of the body is the nutrition of an infinite multitude of living tissue cells. We may think of the human body as a mighty community made up of an unthinkable number of living tissue cells every one of which is an individual, though very dependent, cell. (It is said that 450,000,000,000 red-blood cells in the circulation are destroyed and replaced in every period of twenty-four hours in the life of a normal adult!) We may think of every living cell as being occupied with the serious and important problem of maintaining its own life and at the same time as performing a co-operative production service essential to the maintenance and the benefit—the health and welfare—of the mighty community of cells of which it is an infinitesimal part. Every living human tissue cell depends on other cells for its supply of water, inorganic salts, blood-sugar, amino-acids, fats, oxygen, vitamins, hormones, and other products of cell activity. Every cell is dependent on other cells for co-ordination, co-operation, and protection. Every cell is dependent on other cells for the removal of its secretions, excretions, and wastes, as well as for a supply of essential nutrient material.

The materials (foodstuffs) for growth, maintenance, and replacement are absorbed by the cell from lymph that surrounds the cell. It has been stated several times in this text that every living tissue cell is engaged in the construction and maintenance of its own living protoplasm and in the manufacture of its own special products. The materials for construction, maintenance, repair,

and manufacture are absorbed by the cell from the fluid medium —the lymph—that surrounds the cell. We have traced the preparation of this material for the cell. Every living tissue cell selects from its lymph environment the amino-acid or amino-acids that carry the nitrogen compounds with which it is possible for the cell to build its living structure or repair or replace that structure. Growth and replacement are not possible with any other material. Not all the amino-acids are adequate for such service. We know that at least three of these acids are adequate. They are lysin, tyrosin, and tryptophan. Proteins that do not yield these amino-acids on digestion are inadequate proteins. They cannot furnish the cell with the nitrogen compounds it must have for growth and maintenance. The selective absorption of appropriate amino-acids by the tissue cell is an established fact in physiological chemistry, but it is a process that we do not understand.

The inorganic salts and water are absorbed by the cell and incorporated in the living structure of the cell. They, too, are essential to growth and maintenance. Certain cells build a part of their living substance out of fat compounds. But the chief constituent of the living protoplasm of the tissue cell comes from the amino-acids furnished by protein digestion.

It has been shown that vitamins A, B, and C are requisite to life. Vitamin A is essential to growth. It must be assumed that the vitamins are present in the lymph and absorbed as needed by the cell, but what disposition is made of these mysterious bodies by the cell or how they are used is at present unknown.

Every living tissue cell absorbs from the lymph that surrounds it the chemical substances it requires for the manufacture of its special functional products. Examples of these special products are: bone tissues, red-blood cells, enzymes, internal secretions, milk, teeth, hair, and the mysterious something that enables a muscle to contract, a nerve to hurt, an eye to see, or a brain to think. There can be hardly any question that the results of protein, carbohydrate, and fat digestion, present in the lymph, are all sources from which substances are furnished to the cell for the manufacture of its special products. Nor can there be any question that the inorganic salts are utilized in these productions. We do not know what part the vitamins may play, and we have reason to believe that unknown substances present in the lymph and manufactured by other cells or produced by digestion may furnish

material out of which the living cell manufactures some of its physiological products.

Every active living tissue cell carries on its work of construction, replacement, maintenance, and manufacture of products with the aid of water and the inorganic salts, which it absorbs from the lymph that surrounds it. The sources of these substances have been described. They are absorbed by the cell as needed. They are essential to the normal process of every activity connected with the life of the cell.

Transformation of energy in the tissue cell.—Every living tissue cell is a minute laboratory or power station for the transformation of potential energy into kinetic energy. All the phenomena of cell activity are evidences of the expenditure of energy. This energy is contained potentially in the food that is eaten and in the food that is breathed. The most apparent evidences of human tissue-cell energy are shown as body heat and motion. The muscle-cells of the human body represent over seventy per cent of the body weight. Their chief functions are to put the bones and other parts in motion, perform work, and produce heat.

All the activities of the tissue cells are products of the energy of the tissue cells. The construction of living protoplasm for growth or replacement of the cell structure and the manufacture of all cell products are transformations of the energies of molecules in watery solution in the cell. And the molecules in watery solution are supplied the cell by the molecules of the amino-acids, dextrose, fat, vitamins, salts, oxygen, and probably other chemical compounds in solution in the water that the cell imbibes from the lymph that surrounds it.

The energy of the sun is the source of the energy of the cell. It is said that the energy of the sun reaching the earth in the rays of the sun is the source of all energy as we know it. Plant physiology demonstrates that the formation of the chemical structure and content of plant tissues is a product of the energy of the sun's rays acting on chemical substances in the plant secured by the plant from the air and the soil.

The carbohydrate molecule which we call dextrose is the chief source of energy available in the lymph. It is obvious that the ultimate source of the potential energy of the dextrose molecule is the energy transformed from the sun's rays into the antecedent cellulose or starch formed in the green leaf of a living plant as a

result of the reaction of chlorophyll, carbon dioxide, and water in the presence of sunshine.

The fat molecule has been traced back to an origin from the sugar produced by the plant and the ultimate origin of the amino-acids is in the protein of plants. The energy of the human tissue cell is a transformation of energy that is potential in the dextrose, amino-acids, and fat available in solution in the lymph surrounding the cell, and thus comes by a devious route from the energy of the sun.

Oxidation.—The most common, the largest, and the chief transformation of energy in the human body is what is called an oxidation process. The most familiar oxidations outside the body are the burning of wood and coal. A union of oxygen with the carbon and hydrogen from the wood or coal is an essential part of the process in a wood or coal fire. We call this process combustion or oxidation. It is accompanied by the formation of carbon dioxide and water. The potential energy of the wood or coal is liberated in this process and is thus transformed into heat.

The products of digestion present in the lymph are chemical bodies that contain a great deal of carbon and hydrogen. The carbohydrates are all combinations of carbon, hydrogen, and oxygen. The fats have exactly the same chemical elements, differently grouped. The proteins all contain carbon, hydrogen, and oxygen, with nitrogen. It is obvious that the carbon and hydrogen compounds necessary for decomposition and the release of heat and energy characteristic of combustion (oxidation) are present in the absorptions of the tissue cell and are available there for such chemical decomposition and reaction with the oxygen imbibed by the cell.

We have good reasons for believing that there is a physiological oxidation in the tissue cell between the respiratory food (free oxygen) and the products of the decomposition of carbon compounds furnished by digested foods (dextrose, fat, and, under certain circumstances, the amino-acids) with a consequent transformation of potential energy into active (kinetic) cell energy. The decomposition liberates the energy potential in the foodstuffs and transforms that energy into heat. Carbon dioxide, water, and other products are formed by the union with oxygen.

The chemical elements, carbon and hydrogen, that unite with oxygen in physiological oxidations in the tissue cell are the same

elements that unite with oxygen in the combustion (oxidation) produced when fuel is burned in the kitchen stove or in a railroad engine, a factory furnace, or a forest fire. It may, therefore, be said that the carbohydrate and fatty foods and to some extent the protein foods are *fuel* foods.

The products of fuel combustion (oxidation) are always carbon dioxide and water. The products of physiological combustion (oxidation) are always carbon dioxide and water. The combustion of fuel transforms the potential energy of the fuel into heat. By means of machineries we transform that heat into mechanical energy with which the mechanical work of the industrial world is largely carried on. The combustion of fuel foods in the tissue cell transforms the potential energy of the fuel foods into body heat and physiological function. But this transformation is not a simple one, nor is it well understood. Physiological oxidation is initiated by the tissue cell and its intensity is regulated by the cell. The fuel that is burned is not the living structure of the cell. The heat of physiological combustion does not injure the living protoplasm of the cell. Knowing the intensity of the heat of ordinary fuel combustion, the relatively low temperature of physiological oxidation is at present inexplicable.

Measurement of energy.—By the measurement of heat, we are able to measure the amount of potential energy released and the amount of kinetic energy produced by the combustion of fuel of any sort. Practical and accurate methods and instruments have been devised for the measurement of the amount of heat given off when fuel or fuel-foods are burned. The unit for measuring heat is the calorie. A large calorie represents the amount of heat that is required in order to raise the temperature of one kilogram of water one degree Centigrade. A small calorie, for finer heat measurements, represents the amount of heat required in order to raise the temperature of one gram of water one degree Centigrade. The small calorie is one one-thousandth part of a large calorie. The apparatus for measuring heat values is called a calorimeter.

Under scientific laboratory conditions, it is possible to analyze chemically the respiratory and alimentary intake and weigh the amounts of the known chemical compounds present and thus to measure the potential fuel values involved. It is equally practicable to analyze the respiratory exhalations, the urinary excre-

tions, and the excretions in the sweat, and the rejections and wastes in the feces, and weigh the amounts of the known chemical compounds present, and thus to measure the amount of heat given off by the body at rest or at work. By means of these qualitative and quantitative analyses, we may compare the intake of the body, on the one hand, with the rejections, wastes, and excretions, on the other, and thus measure the chemicals used by the tissue cells. Or, we may measure the fuel values of the intake of the body and compare them with the fuel values of the rejections and wastes, and with the calories given off in the form of heat, and with the heat equivalents of work done.

The amount of each chemical taken into the body balances exactly the amount of that chemical discharged from the body. Nothing is lost. Many such qualitative and quantitative analyses and comparisons have been made. As a result, we know that the healthy body maintains a balance between the amount of any given chemical requirement that it ingests and the total amount of that chemical rejected and discharged in the feces and excreted in the urine or in expired breath. These balances between ingestion and excretion are called equilibriums. The normal adult in good health maintains a nitrogen equilibrium, a carbon equilibrium, an inorganic salts equilibrium, a water equilibrium, and a general equilibrium between his ingesta and his excreta. These equilibriums are disturbed only when the body gains or loses in weight.

There is also an exact energy balance. No energy is destroyed. As a further result of qualitative and quantitative analyses and calorimetric comparisons, we have scientific proof of a balance between the potential energy (heat value) of ingested food absorbed into the blood and the energy produced by such food. The energy produced by transformations in the tissue cell may be measured as heat or as heat equivalents of work (muscular work).

When burned in a calorimeter the heat values of protein, fat, and carbohydrate foods have been recorded as follows (Stohman):

1 gram of protein	yields 5,711 small calories	or 5.7 large calories.
1 gram of fat	yields 9,365 small calories	or 9.3 large calories.
1 gram of carbohydrate	4,182 small calories	or 4.1 large calories.

But not all the food eaten is digested and absorbed into the blood. Some of it simply passes through the alimentary canal and is excreted without having really been *in* the body. It may be indigestible or it may fail of digestion. By analyzing the feces and by securing their heat values it is possible to estimate the amount and calorific values of the foodstuffs absorbed with a given diet. It is obvious that the digestibility of food has a very important bearing on its energy value to the tissue cell. In addition, it must be remembered that the proteins serve another purpose than the development of energy. Of the protein eaten, only seventy per cent is available for energy. Ninety-five per cent of the fats, and ninety-seven per cent of the carbohydrates are ultimately available for oxidation by the tissue cell. This ultimate physiological caloric value has been calculated by Rubner as follows:

1 gram of protein will yield 4,100 small calories or 4.1 large calories of physiological energy.

1 gram of fat will yield 9,305 small calories or 9.3 large calories of physiological energy.

1 gram of carbohydrate will yield 4,100 small calories or 4.1 large calories of physiological energy.

These results may now be summarized in turn.

a) *Protein values.*—The amino-acids are the products of the digestion of protein food and they are the only forms in which the proteins are absorbed into the blood and made available to the tissue cells for the following purposes: (1) The amino-acids are used by the living tissue cell in foetal life, infancy, childhood, and youth for the construction of living growing tissues. No other substance furnishes the tissue cell with the nitrogen it must have for growth. (2) The amino-acids are used by the tissue cell to replace its structural losses. The maintenance of the living cell requires adequate material for the replacement of losses due to wear and tear. This new protein material in the protoplasm of the tissue cell must be built by the cell out of the amino-acids. (3) The amino-acids are used by the living tissue cell for the manufacture of some of the products which the cell furnishes for essential service to the other cells of the body, such as the enzymes, the internal secretions (hormones), the red-blood cells, and the milk of the nursing mother. (4) The non-nitrogenous portion of the amino-acids may be decomposed and oxidized by

the tissue cell for the development of heat or some other form of energy. (5) Protein foods have a stimulating effect upon tissue-cell activity. This influence has been called the specific dynamic action of proteins. It is an influence that has been demonstrated experimentally.

"Thomas, in experiments upon himself, found in general that the proteins furnished by animal foods are more efficient . . . . than those obtained from vegetable foods. Designating the efficiency of cow's milk at 100, he finds that ox meat has a value of 104; fish, 95; crab meat, 79; peas, 56; wheat flour, 40; cornmeal, 30. These numbers represent what he calls the biologic value of the several sources of protein commonly used in our diets."[1]

b) *Carbohydrate values.*—Dextrose and, to some extent, levulose and galactose are the simple sugars produced by the digestion of carbohydrates. Dextrose and probably levulose and galactose are the only forms in which the carbohydrates may be absorbed into the blood and distributed to the tissue cells. The carbohydrate foods may be evaluated in summary, as follows: (1) They bring the tissue cell a potential energy which the cell may transform into its own vital energy, or (2) which the cell may transform into heat for the maintenance of the body temperature. (3) Less protein food is required for the maintenance of health if the regular food supply contains sufficient carbohydrates. The carbohydrate food is then a "protein sparer." (4) An excess of carbohydrate food may be transformed (synthesized) into fat and stored in fat-cells in the tissues. This stored fat may be again changed into carbohydrate (to glycogen and then to dextrose) in case of tissue-cell need. (5) Some part of the carbohydrate food may be used for constructive purposes. The protein structure of the cell nucleus always contains a carbohydrate group. Human milk contains a sugar called lactose.

c) *Fat values.*—The fine droplets of fat emptied into the blood by the lacteals after having been absorbed from the small intestine as fatty acids and glycerine (the products of the digestion of fat foods) and then reformed into fat are available to the tissue cell for the following purposes: (1) The potential energy they carry may be liberated by decomposition and oxidation in the tissue cell after absorption by the cell. Fat may therefore

[1] Quoted from Lusk by Howell, *Textbook of Physiology,* Tenth Edition, p. 920.

serve as a source of cell energy or as a source of heat. These are chief services of fat foods. (2) The fat droplets may be stored in fat cells as body fat and thus be held in storage as a reserve for future use. (3) There are always certain fat groups (fatty acid radicals) in the cell structure (lecithin, for example). Fat therefore serves to a limited extent as a material for the construction of living protoplasm. (4) Fat may be a protein sparer. (5) The fat droplets in the blood may be split into fatty acids and glycerine within certain cells and then used by the cell for the manufacture of its special product. For example, the cells of the mammary gland of the nursing mother secrete milk. The fat in this milk is probably manufactured by the gland cells of the mammae.

d) *Oxygen value.*—Oxygen in combination with other elements is present in all cells and in all cell products. This intramolecular oxygen is present in the food we eat and in the water we drink. Free oxygen is absorbed into the blood from the lung spaces (alveoli). It unites with the products of the decomposition of the fuel foods in the tissue cell and thus takes an essential part in the transformation of potential energy into kinetic energy. This is the main source of bodily heat and muscular work.

e) *Vitamin values.*—Vitamins A, B, and C are essential to growth and to the maintenance of cell life. They are not sources of energy. Their mode of action or nature is not known.

f) *Inorganic salt values.*—The salts are essential to the continuity of normal chemical reactions in the tissue cells and in the products of their activities. The salts are an essential part of all the tissue cells and of all the products of those cells. They are present in and requisite to living protoplasm. They are not sources of energy.

g) *Water values.*—Water is essential to all the activities of the tissue cell—chemical, physical, and vital. It is present in all living protoplasm and in all the substances produced by cells. It is not a source of energy.

Nutritional requirements for constructive hygiene.—The nutritional requirements of the living tissue cell establish the nutritional requirements for the maintenance, improvement, or restoration of health for the whole human organism. We eat, we drink, and we breathe to satisfy the chemical demands of our tissue cells. These demands are for nitrogen, carbon, hydrogen,

oxygen, potassium, calcium, magnesium, iodine, and iron. These chemicals are present in compounds in the protein, fat, and carbohydrate foods we eat and in the water we drink. Oxygen is mixed but not chemically combined in the air we breathe.

Each one of these chemical elements is essential to health and to life, but it may fairly be said that nitrogen, carbon, hydrogen, and oxygen are the most prominent of these essential chemicals.

Nitrogen is a structural part of every tissue cell and is an essential chemical part of the structure of most, if not all, the secretions produced by the various tissue cells. Nitrogen is a requisite for cell structure, growth, replacement, and reproduction, and for the manufacture of cell products. It has been shown that nitrogen reaches the tissue cell as a part of the amino-acids, the final products of the digestion of protein foods. For these reasons, the protein foods from which the amino-acids are derived are absolutely essential to health. The protein foods are sometimes called nitrogenous foods.

Carbon and oxygen in the tissue cell are associated with the chief, if not the only, source of bodily heat and of bodily energy. Carbon and oxygen are found combined with nitrogen and with other essential chemicals in all cell structures and in all cell products, and they are requisite for the physiological oxidation in the tissue cell that transforms potential energy into heat and functional energy.

It has been shown that carbon reaches the tissue cell as a part of dextrose, the digestion-product of carbohydrate food; and in the form of fat-drops, the digestion-product of fat-food; and also as a part of the amino-acid complex, the digestion-product of protein food. All three of these foodstuffs are then fuel-foods, but the carbohydrates and the fats are the important carbon-foods or fuel-foods.

Nitrogen requirement.—The normal healthy individual is said to require 1.5 grams of protein or 0.23 grams of nitrogen for each kilogram of body weight. For the average adult, weighing about 150 pounds (70 kilos), this would require a daily digestion and absorption of about 100 grams of adequate protein. This would mean a daily ingestion of about 120 grams of protein. The nitrogen requirement for the normal adult does not vary in response to ordinary variations of sedentary life or of physically active life. A greater amount is needed to supply the demand for

growth in infancy and childhood and youth and possibly for replacement after excessive muscular work. The tissue cell is a protein machine in which the daily wear and tear does not vary within reasonable limits of operating activity. The amount of nitrogen required is somewhat less with advancing age.

Protein food may be animal protein, such as meat, fish, eggs, or milk; or it may be vegetable protein, such as peas, wheat flour, cornmeal, and beans. The animal proteins are accompanied by lesser amounts of carbohydrate material than the vegetable proteins. The requisite amount of nitrogen may be secured with the consumption of a much smaller amount of animal protein food than with the consumption of vegetable protein. The animal proteins have been shown to be more efficient in satisfying the nitrogen needs of the tissues than the vegetable proteins.

Various students of nutrition have shown that a diet containing much less than 100 grams of protein food each day may be continued for periods of time or even indefinitely with no apparent damage to health and physical efficiency. Chittenden reduced the daily protein factor to 0.75 grams per kilogram of body weight (about 50 grams) daily for the average man with no evidence of injury.

As a consequence of observations such as these, there are advocates of a low protein in opposition to a high protein diet. A daily consumption of from 30 to 50 grams of protein food would be less expensive than a daily ration of from 100 to 120 grams. The proponents of the low protein diet urge, too, that the high protein diet is injurious to the kidneys and a cause of nephritis (Bright's disease).

An argument backed by hygiene and economy is a convincing as well as a persuasive argument. But there is as yet no certain evidence that a high protein diet—100 to 120 grams daily—is a cause of nephritis. And it has been noted that the peoples of the earth in all lands and in all classes, rich and poor, civilized and savage, are prompted by instinctive appetite to adopt a high protein ration. This natural, independent, instinctive selection must be rated as a fact of real significance.

Carbon requirement.—The ration of carbohydrates and fats should furnish about 270 grams of carbon to the tissue cells daily. A small amount of carbon is furnished at the same time by the protein ration.

An adult in good health and at rest burns on the average enough carbon to produce 40 calories of heat per hour per square meter of body surface. Knowing the height and the weight, the surface area may be estimated by using a formula computed by E. F. and D. Du Bois:

$$A \text{ (area) in square meters} = \text{weight in kilograms} \times .425 \times \text{height in centimeters} \times .725 \times 71.84$$

The body is never absolutely at rest. The heart is always beating. Each beat calls for enough energy to force an average of perhaps six ounces of blood into circulation. At this rate, the tissue cells of the heart must oxidize enough carbon to move every six minutes a weight equivalent to that of the whole body and every twenty-four hours a weight of more than 38,000 pounds. The lungs are always at work. Respiration never stops. The muscles involved in breathing average over 23,000 inspirations and expirations in twenty-four hours. The power for such work is a product of the transformation of energy developed by the oxidation of carbon in the cells of the muscles of respiration. The amount of work involved has not been measured.

There are other physiological oxidations that must take place even at times when the body is at rest. The metabolism that goes on in the tissue cells to meet this basic need for energy is called the *basal metabolism.* It is found by measuring in a calorimeter the heat that is produced by the body at rest. It has been found that for the average adult man, the basal metabolism is about 1,600 calories a day; for a woman, 1,300 to 1,400 calories.

In other words, the minimum requirement of the tissue cells, for the purpose of maintaining the body machine in operating condition and doing no work other than that of keeping the body machine going, demands the oxidation in the tissue cells of enough carbon to produce from 1,300 to 1,400 calories of heat for the average woman and 1,600 calories for the average man. During the periods of infancy and childhood, while the body is growing, the basal metabolism is higher. With advancing age, the basal metabolism decreases.

The production of heat is increased by muscular activity. We know by actual measurement that a man asleep may produce 65 calories of heat per hour (basal metabolism); awake and sitting up, 100 calories; standing still, 114 calories; doing severe mus-

cular work, 653 calories (Benedict and Carpenter). It is obvious that the carbon foods (the carbohydrates and fats) should be rationed in proportion to the muscular work being done. The normally active average mature woman produces 2,400 calories and the average mature man 3,000 calories a day. During the war the Interallied Food Commission calculated a per diem dietary of 3,300 calories for men doing an average amount of muscular work for eight hours a day.

Chemical requirements other than nitrogen and carbon ones are usually satisfied by the chemical accompaniments of nitrogen and carbon in the food that is eaten and by the chemicals present in drinking water. It is, therefore, not a matter of ordinary concern that there be an adequate supply of hydrogen, sulphur, phosphorus, sodium, potassium, calcium, chlorine, iodine, or iron in the diet if the diet contains the proper amount of proteins, fats, and carbohydrates.

In some localities, there seems to be a deficiency of iodine in the drinking water, leading to the appearance of goiter in adolescent girls and to a lesser degree in adolescent boys. This chemical inadequacy has been noted in the regions of the Great Lakes and in northwestern United States.

It is not uncommon, too, to find an inadequacy of iron in the chemical income of the body, but ordinarily there is more than the requisite amount of iron in the diet of the average individual.

Vitamin requirement.—The vitamin requirement is amply supplied by any ordinary mixed diet containing fresh fruit, fresh vegetables, milk, and eggs. If the proteins, carbohydrates, and fats are present in satisfactory quality and quantity, the vitamin requirements need give no concern.

Water requirement.—The water requirement is met in part by the water content of all foods in the dietary. In addition, from six to eight glasses of water should be drunk daily between meals.

Oxygen requirement.—This requirement is of two sorts, the free oxygen requirement and the combined oxygen requirement. The latter is met by the oxygen contained in combination with all other chemicals in the various foods eaten and in water. The requirement for free oxygen is met by the respiratory supply. Under ordinary circumstances of good ventilation and clean air for breathing, the supply of free oxygen for physiological oxidations is satisfied.

A *balanced ration* is a mixed diet that contains a proportion of proteins, fats, and carbohydrates that will maintain a desirable nutritional equilibrium. The ordinary proteins, fats, and carbohydrates contain all the chemical elements, all the salts, and all the vitamins needed by the individual. Such a diet contains also a considerable amount of water, but drinking water should be added as a matter of course. Obviously there is no occasion for concern over the free oxygen intake. The lungs will absorb an adequate supply with no thought or conscious effort by the individual.

The selection of the details of a diet should be based on a reasonable appreciation of the age, physical activities, and nutritional reactions of the individual. The diet of the unborn babe is furnished by the diet of the expectant mother. Her food ration should be governed by the fact that she is nourishing herself and the child she bears. She should have a full, mixed, easily digestible supply of nourishing food. Her dietary should be as advised by an experienced physician.

The same general statement applies to the mother and her nursing infant. The baby that is nursed by its mother is likely to be better nourished and to grow more normally than the baby that is fed by the bottle. The diet of the bottle-fed baby should be selected and managed under experienced advice. Otherwise, the constructive hygiene of the infant may be impaired, to the damage of its health and perhaps to the loss of its life.

The child and the youth require a full and varied diet. The protein requirement during this period of growth is relatively greater than in adult life. The normal active physical life of children and young people demands a plentiful supply of fuel-foods—carbohydrates and fats.

The mature adult needs from 70 to 100 grams of protein food daily, regardless of his physical activity, unless that activity is excessive. In the latter case he needs rather more protein. The fuel-foods of the mature adult should be adjusted in proportion to his muscular activity. The sedentary life is satisfied in the average person by an amount of fuel-food that will yield approximately 2,400 calories daily. The person of average weight who works physically eight hours a day will need a supply of fuel-foods that will produce 3,000 or 3,300 calories daily. Those who carry on excessive physical work, lumbermen, stevedores, six-day bicycle riders, and so on, need much more.

The average diets and their heat values, computed for the average adult by several authorities on this subject are recorded by W. H. Howell as follows:

	Moleschott		Ranke		Voit		Forster		Atwater	
	gms.	calories	gms.	calories	gms.	calories	gms.	calories	gms.	calories
Protein	130	533	100	410	118	483	131	567	125	512
Fats	40	372	100	930	56	520	68	632	125	1,172
Carbohydrates	550	2,275	240	984	500	2,050	494	1,825	400	1,640

The nutritional reactions vary with different individuals. Some foods are practically always digested with difficulty. Foods that are easily digested by one person may give difficulty to another. Some foods are practically always easily digested.

Meat is one of the most easily digestible foods. The undigested residue from meat is approximately five per cent. Ninety-seven per cent of the protein in meats and ninety-eight per cent of the fat are absorbed. Fish is generally less digestible than meat. The fats in animal foods (meats and fish) are more easily digested than the fats in vegetable foods. Both are less easily digested than the protein of meat and fish. Eggs, milk, meat, and oysters are the most easily digested of our foods. Milk is more completely digested by young children than by adults. Bread is easily digested. The cereals are fairly easily digested. Cornstarch, sago, tapioca, and rice are easily digested; oatmeal and barley meal, not so easily.

The legumes (peas, beans, and lentils) are better digested when mixed with other foods than when eaten alone. In any event, they are less digestible and yield a greater residue in the feces than the animal foods, breads, and cereals already mentioned. The digestibility of the legumes is, however, not difficult for the normal digestive tract.

The vegetables (potatoes, carrots, turnips, parsnips, and beets) are a little less easily digested than animal foods. They contain varying amounts of indigestible cellulose tissue which has a value as an intestinal irritant that promotes the discharge of the feces. A certain amount of roughage (undigested and unabsorbed residue) is important to the satisfactory evacuation of the bowels. The potato is the most important food in this group. It is digested fairly easily. The green vegetables are chiefly valuable as sources of vitamins and roughage.

Fresh, ripe fruit is usually easily digested. Such fruit is a

source of vitamin. Green fruit is not easily digested. Cooked fruit is more digestible than green or uncooked ripe fruit. Nuts are not so easily digested as fruit. They contain protein, fat, and vitamin.

Personal idiosyncrasy not infrequently alters the nutritional reaction of the individual so that he must govern his selection of dietary details with reference to the limitations and possibilities of his own digestive powers.

Index of general nutrition.—Body weight is the best index we now have of general nutrition and health. A number of investigators have calculated the average and mean weights for individuals of different heights for both sexes. Some of the great insurance companies have studied the death rates of their policyholders, comparing the death rates of large groups of persons of different weights but of the same height, age, and sex. As a result we have an approximately accurate record of "normal" or average weight for persons of different heights at different ages, and we know something about the relationships of overweight and underweight to health in the different age periods.

Whether or not the weight-height ratio is a reliable index to the state of nutrition or health in children, it would seem that the mortality experience of insurance companies indicates definitely that overweight at certain ages involves serious danger to the lives of their policyholders, the degree of danger increasing with the excess in weight over the average for height and age for certain ages. At younger ages, however, a limited amount of overweight appears to be of advantage, or associated with more favorable mortality conditions, overweight persons of such ages having uniformly lower death rates for tuberculosis. The records indicate that after 35 years of age, overweight, even in relatively small amounts, begins to be dangerous, the seriousness increasing with advancing age and amount of overweight. The following statements, based on the records of insurance companies,[1] are taken from the Statistical Bulletin of the Metropolitan Life Insurance Co., for November, 1922.

Among short men—that is, those below 5 feet 7 inches in height—at the age period 40 to 44 years, an excess of 20 per cent in weight involves an added mortality of 30 per cent above the normal. A 40 per cent excess in weight in such individuals involves an increased mortality of nearly 80 per cent. Among tall men—that is, those over 5 feet 10 inches in height—the adverse situation is even more marked; for among them, at ages 40 to 44, a 20 per cent excess in weight carries a 40 per cent increase in mortality, and a 40 per cent excess in weight doubles the mortality.

[1] Report of the Joint Committee of the Actuarial Society of America and the Association of Life Insurance Medical Directors, New York, 1918.

On the other hand, underweight presents a different picture. It is a serious impairment in early adult life, especially among tall men. Persons who are over 5 feet 10 inches and who are 20 per cent below the average weight for their height show an increased mortality of 30 per cent. Persons 30 per cent underweight have a 50 per cent excess mortality at these early ages. But from age 40 onward there are apparently no such penalties for underweight, and this condition, in fact, becomes a distinct advantage; for these are the people who have the best mortality rates.

It would seem that the records of insurance companies indicate that there is an optimum weight—that is, a weight-height ratio in relation to age that is associated with the most favorable mortality experience, and that this optimum weight, or best build, is not the average build. It is stated that those who weigh between 10 to 20 per cent below the average show the optimum condition for longevity at most ages beyond early adult life.

Continuing the question of optimum weight, or best build, as indicated by insurance records, it is stated in the Statistical Bulletin for March, 1923, that at ages under 30 years, the lowest mortality rates among insured persons are found in those whose weights are above the average, an excess of weight of about 10 pounds above the average producing the most favorable mortality rates between the ages of 20 and 24 years. This excess tapers off until about age 30, at which age the lowest mortality is found among persons of approximately average weight. Beyond age 30, the lowest mortality is found among persons whose weights are below average, the amount of underweight associated with the most favorable mortality increasing with advancing age. At age 50 optimum weight appears to be, on the average, 30 to 40 pounds below the average weight for that age.

Discrimination must be made between types of build of overweight persons, it being shown that among overweights having a large chest capacity, the conditions of mortality are more favorable than among those of small chest capacity. Overweights who have large trunks are better risks than those having small chests and large abdominal girth.

On the assumption that the average weight is the best weight, tables of average weights lead to the erroneous supposition that weight should continue to increase with advancing age. While this increase is of very common occurrence, the insurance records indicate that, within certain limits, this excess weight increases the insurance risk and should be carefully avoided.

These records, together with clinical evidence, suggest that through restriction of diet and proper indulgence in some form of exercise conditions premonitory of organic impairment and eventual breakdown of the circulatory and excretory systems may be averted in many instances.[1]

See Appendix for Standard Table of Heights and Weights.

[1] United States Public Health Service, *Public Health Report,* Volume XXXVIII, No. 23, June 8, 1923, Washington, D.C., p. 1271.

CHAPTER XIV

EXCRETION: AN ESSENTIAL PRINCIPLE OF CONSTRUCTIVE HYGIENE—PRIMARILY A PRINCIPLE OF CONSTRUCTIVE SOMATIC HYGIENE

Explanation of excretion.—The chemical income of the cell is balanced by its chemical outcome. Attention to this fact has been called in the preceding chapters. We have noted that all living cells, plants, or animals maintain this balance and that as long as a living cell maintains a constant weight the amount of each chemical element that it absorbs is exactly balanced by the amount of that chemical element that it discharges. The medium that surrounds the cell is the source from which it absorbs its chemical intake and is the receiver of all the chemical compounds that leave the cell. This medium is characteristically a fluid medium, an air medium, or a combination of the two.

The fluid lymph is the medium that surrounds the human tissue cell. It has been shown in the preceding pages that the lymph is the immediate source from which the tissue cell absorbs oxygen, water, salts, vitamins, sugar (dextrose), amino-acids, fats, hormones, and other chemical bodies that have been diffused in solution from the blood into the lymph. The lymph is also the receiver of all the chemical outcome from the cell that it surrounds. This chemical outcome contains all the chemical elements that were present in the chemical intake, with this difference—the chemical elements present in the outcome are commonly grouped into different compounds from those present in the income. All the chemical elements are present. They are simply differently arranged. Nothing is lost.

Useful products.—The chemical outcome from the cell may contain useful products. The chemical outcome from the living tissue cell is made up in part of useful products that have been manufactured by the cell out of the chemicals that it has received. The manufactures of the ductless glands, to which we have referred before, are synthetic products of tissue-cell activity and are examples of chemical substances produced by cells and discharged by cells into the lymph that surrounds them. Such products of cell activity are known as secretions. The secretions are usually, but not always, useful to special groups of tissue cells. The secre-

tions of some tissue cells, the thyroid glands for instance, are directly or indirectly essential to the life of all the tissue cells.

Waste products.—The chemical outcome from the tissue cell always contains waste products that are called excretions. In addition, the chemical outcome from the living tissue cell contains compounds that are largely useless. These compounds are parts of the chemical substances that have been broken down by the cell in the performance of its normal functions. (1) Some of this breaking down is due to the wear and tear of the living structure of the cell. We may think of this as wear and tear of the structure and the machinery with which the cell does its work. It is largely wear and tear of protein compounds that are present in the cytoplasm and the nucleoplasm. (2) Other compounds are broken down by the cell in the manufacture of its special products. If a cell is making tears or if it is manufacturing milk or producing enzymes, it is constructing those special products out of the "raw" materials that come to it from the lymph. This construction is accompanied by an accumulation of "residues," "scraps," "shavings," "tailings," and other unused or useless wastes. These wastes are commonly discharged by the cell into the lymph that surrounds it. (3) Other substances are broken down by the cell in the chemical transformations that are requisite to the development of the energy of the cell. The cell performs its work with the potential energy contained in the chemical compounds it absorbs from the lymph. This transformation of potential to kinetic energy is accompanied by the production of chemical wastes that are discharged from the cell. These wastes are largely combustion wastes and may be likened to the gases, smoke, ashes, and cinders from an industrial plant. (4) It must be noted further that certain tissue cells are wearing out and dying all the time. These dead cells are dissolved (digested) in the lymph or other body fluid that surrounds them. Their chemical structure is broken up and the resulting chemical compounds are absorbed into the blood circulation and discharged from the body.

Summary of sources.—The sources of excretions and secretions may all be summarized. The chemical products of the living tissue cell are: (1) products of the wear and tear of the day's work on the living protein structure of the cell; (2) by-products of energy-transforming chemical reactions upon lifeless sub-

stances used by the cell to do its work, produce heat, and perform its other functions; (3) lifeless products of the synthetic chemistry (the manufacturing processes) of the cell; (4) living products of the synthetic chemistry of the cell, as such forming the growing structure of the cell or the structure of new cells or the material with which the structure of the cell is repaired. In general, the secretions are synthetic or built-up products prepared by the cells for useful purposes, see (3) and (4) above, and the excretions are in general decomposition, or broken-down, used products and waste products, see (1) and (2) above. Some of the excretions are irritating and even poisonous to the tissue cells. But it must be repeated that some secretions are useless and even poisonous, while some excretions are useful.

The lymph.—The lymph has a safeguarding relation to the excretions that it receives from the tissue cells. The chemicals that leave the tissue cell are received into the lymph that surround the cell. They influence the physical and chemical state of the lymph and, in turn, are influenced by the physical and chemical state of the lymph. Important chemical reactions occur in these spaces between cells and in other extra-cellular spaces filled by the lymph. The temperature and fluidity of the lymph, its alkaline reaction, its chemical events, and its currents of osmosis and diffusion maintain a constant, neutralizing, diluting, safeguarding influence upon the excretory wastes that come into it from the cells. Every one of the unknown billions of these living cells is thus surrounded by a safeguarding zone of fluid lymph that is at the same time both a source of essential supplies and a medium of essential protection. Some of the cell excretions are irritating and poisonous. The neutralization and removal of such excretions is requisite to health and life. A continuous failure to remove any single excretion would lead to an accumulation of that excretion in the tissues and thus to the serious injury of the tissue cells.

Excretions in the lymph.—The excretions in the lymph are diffused into the blood in the surrounding capillaries. The lymph about the cell is relieved by the blood of its content of chemical compounds made up of tissue-cell secretions and excretions, and of the results of chemical reactions that take place in the lymph. With those gland cells that discharge their secretions or excretions externally, the chemical output may leave the cell and finally

leave the body without passing through the lymph and the blood on the way out.

In the main, however, the chemical outcome from the cell—the secretions and the excretions from the cell—and the products of chemical reactions in the lymph surrounding the cell pass thus by filtration, osmosis, and diffusion from the lymph into the blood capillaries and are then carried into the general blood circulation. By this arrangement it follows that all the cell secretions and all the cell excretions, with the exception noted above, are diffused into the blood and distributed by the blood.

The blood.—The blood is a carrier and distributor of chemical income and of chemical outcome. One must think of the blood then as a carrier of fuel-foods (dextrose and fats) and of construction and manufacture-foods (amino-acids, dextrose, fats, and salts) to the lymph for the tissue cells and also as a collector, carrier, and distributor of manufactured products, factory wastes, and worn-out parts, discharged from the cells into the lymph or produced in the lymph. Incidentally the blood has other important functions that need not be mentioned here. In this manner every living tissue cell may secure from the blood capillaries not only the digestive products of the cells of the alimentary tract and the respiratory products of the lungs brought to the cell by the blood but also the products of the activities of all the living cells of the whole body and chemical solutions of those that die which are brought to the cell by the blood. Thus there is distributed to the intimate environment of every living tissue cell the internal secretions from the endocrine glands (e.g., the thyroids, the thymus, the pituitary, the pineal, the adrenals, the Islands of Langerhans in the pancreas—the source of insulin—etc.), and all other chemical products of cell activity, inter-cell activity, and cell distribution, except those of the external secretions, and external excretions. The chemical income and the chemical outcome are all present in the blood capillaries—the useless and dangerous as well as the useful and essential.

Disposition of poison.—The poisons in the cell excretions are neutralized and the excretions are finally eliminated from the body. But under normal ordinary conditions, the irritating and poisonous cell products that reach the blood do not return to damage the living cells. Having once passed out of the lymph spaces and into the blood capillaries, physical influences tend to

prevent their return; chemical changes remove some or all of their poisonous properties; and the secretory and excretory action of certain organs and glands removes them from the blood and discharges them out of the body. The most important of these excretory organs are the liver, the kidneys, the lungs, and the skin.

Recapitulation.—During the life of the cell, it is continually subject to wear and tear. The used-up parts of the living structure of the cytoplasm and of the nucleus are removed by the cell and replaced with new living material. This structural wear and tear is greatest during the periods of growth—infancy, childhood, and youth—and under the influence of febrile and emaciating diseases. During the life of the cell it is continually manufacturing special compounds for its own functional use and for the use of other cells. This manufacture is accompanied by waste products that come from the chemical materials used in the process. These waste products must be removed from the point of formation, either in the cell or from the lymph that surrounds the cell. During the life of the cell, it is continually using carbon compounds and free oxygen for the production of heat and energy with which to carry on its functional service. This process is apparently one of physiological oxidation. It is accompanied by the formation of the waste products of combustion. These products must be removed from the cell and its environment. After its death the cell body and its nucleus must be regarded as lifeless wastes. They too must be dissolved and removed from the environment of the remaining neighboring living cells.

The cell, then, during its life, turns out: (1) useful synthetic products; (2) useless waste products; and (3) useless products of structural wear and tear. We have called the useful products secretions and the useless products excretions. This is not a wholly accurate classification. Some excretions are very useful and some secretions are useless.

It is evident that the living tissue cell has an individual history. It comes from a pre-existing cell. It depends on other cells for its supply of essential chemical compounds and of free oxygen. It builds its own living structure, repairs and replaces the wear and tear of that structure, develops its own power, and manufactures its own useful functional products for service to itself and for service to other cells. It produces other similar cells. It dies, and if this death occurs before the simultaneous death of all the other

cells of the body, it is dissolved and removed. Most of the various types of tissue cell are replaced, when they die, by similar cells. Certain tissue cells, the nerve cells for instance, are not replaced in case they die. But under normal conditions, the cells that are not replaceable do not die during the life of the individual of which they are a part. This process of cell change involving the "birth," growth, deterioration, and death of a cell is called cytomorphosis.

Internal excretions.—It is obvious from the preceding discussion that there are internal excretions and external excretions, even as there are internal and external secretions. The excretions that are discharged by the cell directly into the lymph and blood that surround it may be described as internal excretions. The excretions that are discharged by cells from the body without further relationship to the lymph or blood circulations may be described as external excretions.

The logical fact should again be emphasized that the internal excretions are inevitably diffused throughout the blood distribution. Consequently there is very real danger in any interference with the functional activities of those organs that neutralize and counteract the poisons in the internal excretions, and there is very real danger in any interference with the adequate elimination of these poisons by way of the external excretions.

While our knowledge of the exact nature of the various internal excretions is incomplete, we nevertheless possess a sufficient amount of scientific information to give us a rational understanding of the main facts involved. These facts relate to the chemical history of the products of the daily wear and tear (the "depreciation") of the cell structure, the formation of wastes that accompanies the manufacturing activities of the cell, and the combustion products that arise from the transformations of energy that furnish the cell with power to do its work.

Certain internal excretions are derived from the destruction of tissue protein.

Ammonia; urea.—We have reason to believe that the daily wear and tear of the living protein structure of the tissue cell is a physical and chemical process that involves the formation and internal excretion of ammonia and ammonia salts. These ammonia substances are irritating and would damage and destroy the tissue cells if permitted to accumulate in the circulation of the

blood. There is evidence that the liver converts ammonia and ammonia salts into urea. It would appear therefore that ammonia is probably an internal excretion of the tissue cell produced by the digestion in the cell or in the lymph spaces about the cell of damaged and worn-out protein structure of the cell, that this ammonia and these salts of ammonia are carried away in the blood stream, and that the liver transforms these ammonia bodies that come to it, converting them finally into urea. There is doubt that the liver is the only source of urea, but the facts now known indicate that it is probably the most important source. The urea formed in the liver is emptied into the blood capillaries of the liver cells and is carried away into the general circulation. Urea is therefore an internal excretion of the liver cells. The kidneys finally remove most of the urea from the blood. The sweat glands remove a small percentage of the blood urea. The urea of the sweat and the urine is an external excretion of the kidneys and the skin.

Nucleic acid; xanthin, hypoxanthin, and uric acid.—We have reason to believe that the daily life of the tissue cell involves in addition a special structural wear and tear of its nucleus. There is not only a constant structural change in the living protein cytoplasm of the cell but also in the living protein structure of the nucleus of the cell. The biochemist has shown us that nucleic acid is a characteristic of the chemical structure of all cell nuclei. There is good evidence that the day's work of the tissue-cell nucleus is accompanied by the damage or destruction of its own structural material, with the consequent liberation of nucleic acid. The liberation of nucleic acid from the nucleoprotein of the nucleus is accomplished by the influence of autolytic enzymes in the tissue cell. Another group of enzymes act on the nucleic acid that has been released and break it down into a number of chemical compounds that are known as the purine bodies. These bodies appear in human urine finally as uric acid, xanthin, and hypoxanthin.

It may be said then that the internal excretions that arise from the damage or destruction of cell nuclei are in large part products of the digestion of the worn-out nucleoprotein of the cell. These products of the influence of the autolytic enzymes of the cell may be designated in the order of their probable appearance as follows: (1) nucleic acid; (2) purin and pyrimidin; (3) phosphoric acid,

adenin, guanin, adenosin, and guanosin; (4) xanthin and hypoxanthin; and (5) uric acid.[1] There are other compounds produced in this sequence of chemical events, but they are not well known.

These chemical changes that take place in the process of removing damaged and worn-out protein material arising from the wear and tear of the tissue cells probably occur in the tissue cells, in the lymph about the tissue cells, and in certain special organs of the body, notably the liver. For instance, uric acid is one of the end-products of the internal excretion of worn-out nucleoprotein. The enzyme that influences the partial oxidation of xanthin and hypoxanthin into uric acid in the human body is found only in the liver, and so far as we know uric acid is formed only in the liver in human beings.

We have, then, a rather complicated series of related chemical bodies produced in the routine of the internal excretion and removal of damaged and useless nuclear material. Nucleic acid is probably the earliest product in this group and doubtless appears as an internal excretion in the cell itself and in the lymph that surrounds the cell. Uric acid, xanthin, and hypoxanthin are found as such in the urine. These end-products of the destruction of the nuclear protein of living tissue cells are available in the urine for the scientific study and measurement of influences that affect the activities of cell nuclei.

Creatin and creatinin.—Furthermore, we have evidence that the breaking down of structural protein used up in the daily life of the tissue cell is accompanied by the formation of two other constant internal excretions known as creatin and creatinin. These chemical bodies are always present in the muscle tissues and in the blood. Creatinin is also an external excretion, since it is normally present in the urine. Creatin does not appear in the adult urine except under unusual conditions, such as starvation, fevers, menstruation, pregnancy, and in mothers while nursing their infants. Creatin is normally present in the urine of children. All these conditions in which creatin appears in the urine are conditions of excessive tissue-cell destruction.

Creatin appears in the lymph and blood as an internal excretion. Some authorities regard creatinin as a product of some

[1] It is not expected that the student will memorize these chemical names. They are given here to emphasize the complexity of the process involved.

obscure action upon creatin. If this is the case, creatin is transformed into creatinin and creatinin is discharged from the body in the urine. Other authorities hold that creatin and creatinin are independent products of the breaking down and removal of used structural protein from the tissue cell.

Regardless of this difference of interpretation of facts as they are now known, it is evident that these two chemicals are products of internal excretion, and that creatinin as it appears in the urine is an index of the wear and tear of the living structural protein of the tissue cell.

Sulphates and phosphates of protein origin.—There is good evidence that the wear and tear of living tissue protein is a source also of internal excretions formed by the oxidation of the sulphur in this used-tissue protein. Such internal excretions of sulphates are end-products of protein destruction. They are removed by the circulating blood and finally eliminated in the urine as external excretions.

The same events take place in the destruction and removal of the tissue proteins that contain phosphorus. The end-products of these chemical changes appear as phosphates and are eliminated as such in the urine.

Inorganic salts of structural origin.—The alterations, if any, that are made in the inorganic salts that go into the structure of the cell and are released on the displacement or destruction of the cytoplasm or the nucleus are not distinctive and display no special features in the internal or external excretions.

Summary.—The internal excretions arising from the destruction of damaged and used protein material from the living cytoplasm and nucleoplasm of the tissue cell include (*a*) probably ammonia and ammonia salts and products of their reactions with other chemical compounds; (*b*) nucleic acid and a number of chemical compounds derived from nucleic acid; (*c*) creatin and perhaps creatinin; (*d*) sulphates; and (*e*) phosphates.

Certain internal excretions are derived from the destruction of special protein products of cell manufacture.

We have no knowledge at present of the chemical substances that arise as wastes in the manufacture or service of special protein-cell products. There may be no such wastes in the manufacture or physiological use of enzymes or their antecedents or in the manufacture of the protein in human milk. There may be no

such wastes in the production and utilization of the internal secretions, assuming that they are of protein origin. The probabilities, however, are that the manufacture of such special products is accompanied by wastes and that these products are susceptible to deterioration, wear, tear, and destruction.

We have no knowledge of the chemistry involved in the internal excretion of enzymes, or hormones, assuming that these substances wear out.

We do not know the excretory history of the vitamins, assuming that a vitamin may serve its purpose and be no longer useful.

Certain internal excretions arise from the transformation of energy under the influence of the cell.

Lactic acid, acetic acid, carbon dioxide, and water.—There is convincing evidence that the transformation of the potential energy carried by the carbon compounds brought to the cell into the kinetic energy that enables the cell to do its work is accompanied by the formation of carbon dioxide and water as end-products. The chemical history of the events that lead to the formation of these internal excretions, carbon dioxide and water, is not understood. A number of chemical changes undoubtedly occur in this transformation that convert dextrose, fats, and the deaminized amino-acids into carbon dioxide and water. There is convincing evidence that dextrose is first influenced by insulin, an internal secretion of the pancreas. This influence probably takes place in the tissue cell and leads to the synthesis of lactic acid. After the formation of lactic acid, other compounds may be formed before oxidation occurs. The stages of oxidation are possibly a conversion of acetic aldehyde, a product of lactic acid, into acetic acid, then into formic acid, and finally into carbon dioxide and water.

The fact that the rapid physiological oxidation (combustion) of dextrose and the other carbon compounds is accomplished without excessive heat is in contrast with the ordinary phenomena of combustion. The end-products of physiological combustion and commercial or domestic combustion (in a factory furnace or a kitchen stove) are carbon dioxide and water, but the accompanying physical phenomena are different and unexplained.

It may be stated then that there are a number of internal excretions arising from the uses made by the tissue cell of the energy-carrying carbon compounds; that the chemical history of

these internal excretions is not well understood; that these products are acid, mainly lactic acid; and that the end-products are carbon dioxide and water. These two end-product internal excretions finally become external excretions. The carbon dioxide is largely eliminated from the body by the lungs. The water is eliminated mostly in the urine and the sweat.

External excretions.—All the useless excretions are finally removed from the body. We may refer to these eliminations as external excretions. The external excretions finally restore to the air and the soil every chemical element received from those sources for the nutrition of the body. The only irregularities in this sequence are in the event of death and in the secretion of milk for the nursing infant. However, when one dies his body is decomposed and its chemical content is finally restored to the air and the soil. The milk furnished the nursing infant is a combination of secretions and excretions from certain tissue cells of its mother. The mother's milk supplies the tissue cells of the infant with the chemical compounds they must have in order to live and grow. But this chemical income of the infant finally becomes chemical outcome and all the chemicals involved are in the end eliminated by the infant as external excretions. It may be added, that the chemical compounds in the foodstuffs carried to the prenatal child (the unborn babe) by the blood of the mother are in part returned to the blood of the mother as excretions from the child and ultimately eliminated by the mother and in part they remain in the cells and tissues of the child until after its birth. They finally become external excretions of the child.

The normal excretions are contained almost wholly in the urine, the breath, the feces, the sweat, the dead skin cells that are constantly leaving the surface of the body, and the menstrual flow of women.

The kidneys are concerned with the elimination of urine, the lungs with the breath, the large intestine or bowels with the feces, the skin with sweat and with the exfoliation of dead skin cells, and the female genital tract with the menstrual flow.

The kidneys.—There are two kidneys in the normal human being. Each is about the size of one's fist. They are the most important organs concerned with the external elimination of the nitrogenous rejections and wastes that get into the blood. The entire blood supply of the human body is under the constant and

effective influence of the kidneys, because a large proportion of the total blood supply of the body is flowing continuously through its two kidneys. These excretory organs are constantly removing unused, useless, and poisonous rejections and wastes from the circulating blood.

This removal is a physical and chemical process applied by certain groups of kidney cells to the blood plasma brought to them in the capillaries of the kidney. The blood that comes to the kidney is distributed to the excretory and secretory cells of the kidney in a system of branching arteries that in their final minute subdivisions break up into capillaries that supply blood to about sixteen thousand unit groups of these cells in each kidney. Each unit group is called a urinary tubule. There are many capillary subdivisions to the blood supply of each urinary tubule. It is reported that there are 2,000,000 gland tufts (glomeruli) in each kidney eliminating urinary excretions into the tubules. Each one of these capillary networks is made up of a considerable number of microscopic loops, so that the blood that comes to each kidney is finally exposed to the tissue cells of the urinary tubules of that kidney in the tiny channels or streams of an enormous number of microscopic loops and canals in the capillary tufts and networks that bring blood to the urinary tubules. By this arrangement every molecule carried in the blood to the kidneys is finally exposed to the secretory and excretory influence of the kidney cells that make up the structure of the urinary tubules. The physiological action of these cells is such that they remove excesses of water, inorganic salts, and nitrogenous and other substances from the blood. They protect the tissue cells of the body by removing their waste and poisonous products from the circulation.

The urine secreted by the urinary tubules is carried by those tubules to two common canals, one leading from each kidney, called the ureters. Each ureter empties into the bladder. There is a constant trickle of urine into the bladder from the ureters. When the amount of the urine in the bladder increases to a point at which it exerts a sufficient pressure on the bladder, the desire to urinate arises. Under certain abnormal conditions, and sometimes in old age, these normal stimulations are obstructed. The consequent retention of the urine may then become a serious menace to health and to life.

The normal daily output of the kidneys amounts to 1,500 or

1,700 cc. of urine for the average adult human being. This amount varies with the amount of fluid ingested, the amount of perspiration, and changes in the temperature and humidity of the surrounding air.

There are two general sources of the internal excretions that finally reach the kidneys. In our preceding discussions, we have considered the more important internal excretions. We have noted such excretions resulting from the damaging and destructive wear and tear of the living structure of the cell; and from the wastes that accompany the manufacture of special products by the cell or from the service deterioration of those products; and from the chemical events that accompany the transformation of potential to kinetic energy by the cell. It has been pointed out that these internal excretions are carried away from the tissue cells and the lymph that surrounds them by the blood, and that the blood becomes therefore a carrier of the internal excretions.

But there is another very important source of internal excretions from which come irritating and damaging chemicals that reach the blood and would easily and inevitably injure the tissue cells and finally destroy the health and life of the body itself if they were uncontrolled.

These chemical compounds are to some extent not excretions at all, since a large proportion of them do not at any time enter into or take part in the nutritional affairs of the tissue cell. They might better be called rejections.

This excretory material comes from the small and large intestines. It is made up of the following: (1) The excess digested protein material absorbed from the digestive tract. More amino-acid is absorbed here than is needed by the tissue cells. (2) Other protein and ammonia compounds are absorbed into the blood from the intestinal tract. Such chemical bodies as these are controlled by the liver. The amino-acids are deaminized probably in the liver. The poisonous ammonia radicle is converted into urea in the liver. The ammonia salts that come to the liver from the intestine are also converted into urea by the liver. (3) The protein putrefactions that take place in the large intestine yield a group of poisonous compounds known as indol, skatol, phenol, and cresol. These products are in part excreted in the feces and in part absorbed into the blood through the walls of the large intestine. These compounds in the blood are oxidized and then conjugated with

sulphuric acid. They are finally eliminated by the kidneys as harmless conjugated sulphates.

The kidneys, therefore, remove from the blood a large part of the internal excretions discharged therein by the tissue cells, and a large part of the unused and poisonous materials absorbed into the blood through the walls of the small and large intestines.

The urine contains all the external excretions eliminated by the kidneys. The urine is made up of a great variety of chemical compounds. For our purposes they may be satisfactorily classified as: water, inorganic salts, nitrogen compounds (urea, purine bodies, creatinin, etc.), and conjugated sulphates. A discussion of these excretions has been covered in a preceding section of this text.

The lungs.—The lungs are the chief organs concerned with the removal of carbon dioxide from the blood. They remove also a relatively small amount of water and they take a very important part in the regulation of the body temperature because of the heat that is abstracted from the pulmonary blood in warming the respired air and in vaporizing the water that is excreted by them. There is real truth in the saying that the lungs cool the blood.

Each 100 cc. of venous blood that comes to the lungs contains about 45 cc. of carbon dioxide. Each 100 cc. of arterial blood leaving the lungs contains about 38 cc. of carbon dioxide. Seven cubic centimeters of CO_2 are removed by the tissue cells of the lungs from each 100 cc. of blood that passes through the pulmonary capillaries.

The inner surface of the lungs has a total area of about ninety square meters, which is about one hundred times as large as the total area of the skin surface of the entire body. This inner surface of the lungs is in direct contact with the air in the spaces (the alveoli) of the lungs. This surface is the outer surface of an extraordinarily thin membranous wall that forms the lung tissue. This membranous wall contains the blood vessels that bring blood from the heart to the lungs, the capillaries into which those afferent vessels (the pulmonary arteries) finally subdivide, the pulmonary veins (the efferent vessels) into which the capillaries empty and which carry the blood back to the heart, and, in addition, this thin membranous tissue contains the lymph circulation and the nerve supply of the cells that form the lung tissues.

The removal of carbon dioxide from the blood is accomplished by the lung cells that form the thin membranous wall between the lung capillaries and the air spaces of the lungs. The number of these capillaries is enormous. Their size is microscopic. They are so small and shallow that each red-blood cell is exposed separately to the wall of the capillary as it passes through the capillary canal. By this arrangement, every few minutes, the entire blood supply of the body is spread out in the pulmonary capillaries in a thin film enormously less than one-millionth of an inch deep. This thin network film of blood covers an area of more than 1,260 square feet in the membranous walls of the lungs. During the single second or lesser amount of time in which the red cell or other equivalent microscopic amount of blood fluid or other blood content is exposed to the influence of the tissue cell of the lung, the tissue cell removes something like 16 per cent of the carbon dioxide present in the blood stream that comes thus under its influence. This removal of carbon dioxide in the lungs is a physical process. The lung cells that form the tissue walls between the blood capillaries on one side and the air spaces of the lungs on the other constitute a membrane that separates the gases in the blood in the capillaries from the gases in the air spaces of the lungs. The partial pressure of the carbon dioxide is greater in the venous blood entering the capillaries than the partial pressure of the carbon dioxide in the air spaces. The tissue cell plays a passive part in the diffusion of the gas from a point of high tension to a point of low tension. The carbon dioxide that is thus emptied into the alveoli of the lungs is finally expelled in the expired air. But this is not wholly a simple process. The total capacity of the lungs is roughly 4,700 cc. In quiet breathing, the intake and output is about 500 cc. This is called the tidal air, or tidal capacity. A quiet inhalation may be continued to the point of deepest inspiration possible. It is estimated that this complemental capacity or complemental air amounts roughly to 1,600 cc. in addition to the 500 cc. of tidal inspiration. A quiet exhalation may be continued into the greatest possible expiration of air. This supplemental capacity or supplemental air amounts to 1,600 cc. in addition to the tidal exhalation of 500 cc. But after all the air has been expelled from the lungs that one can exhale voluntarily, there remains a considerable amount of residual air. The residual air amounts to approximately 1,000 cc. The vital capacity of the lungs is obviously the sum of

the supplemental air plus the complemental air plus the tidal air, or 3,700 cc.

It is obvious that the removal of the carbon dioxide from the small diverticula in the air spaces of the lungs is a process of diffusion and mixing with the inspired air. It is estimated that there are 725,000,000 of these air pockets in the lungs.[1] A normal quiet inhalation fills the trachea (windpipe), the larger bronchi, the smaller bronchi, and the bronchioles before the air inhaled reaches the air spaces of the lungs. The trachea, bronchi, and bronchioles are tubes that connect the air spaces of the lungs with the throat, the mouth, and the nose. These tubes are dead spaces so far as their relation to actual respiratory exchange is concerned. They contain roughly 140 cc. of air. So each tidal inspiration of 500 cc. would force 360 cc. of air into the air spaces beyond these dead spaces. Since the supplemental and residual air amounts to a reserve of 2,600 cc., it follows that quiet breathing is a process of addition and displacement of 360 cc. of air in this reserve of 2,600 cc. This is a process of comparatively slow ventilation by diffusion, mixing, and partial exchange of air between 360 cc. of "new" air and 2,600 cc. of "old" air.

Under the influence of muscular exertion, with a consequent increase in the formation and internal excretion of carbon dioxide, there comes a rapid increase in heart rate and in respiratory rate. The blood brings an increased amount of carbon dioxide to the lungs. The increased amount comes in a more rapid flow of blood. The greater tension of carbon dioxide in the lung capillaries leads to a greater diffusion of carbon dioxide through the tissue cell membranes of the lungs. The air spaces of the lungs become filled with a greater amount of carbon dioxide. Meanwhile, the larger amount of carbon dioxide in the general blood circulation has reached the respiratory nerve centers in the central nervous system. This increase in carbon dioxide in the blood supply of the respiratory nerve centers stimulates them to greater activity. The respiratory movements of the lungs are consequently increased in extent and in rapidity. The air spaces are, therefore, more rapidly and completely ventilated and the excesses of carbon dioxide in those spaces are more rapidly removed, thus protecting the bodily tissues

[1] C.-E. A. Winslow, *Healthy Living* (Charles E. Merrill Co.), Book II, p. 102.

from the damage that would follow an accumulation of carbon dioxide in the circulation.

The external excretions of the skin.—The skin has a number of important functions other than that of excretion. (1) It offers a protective surface that is not easily penetrated by many of the pathogenic micro-organisms. (2) It is a sensory surface containing nerve organs and fibers that respond to and carry sensations of pressure, temperature, and pain. The various nervous reflexes that follow these sensations enable the body, in consequence, to adapt itself with greater safety to changes in its environment. (3) Its cells are specialized in certain regions to participate in the formation of the special senses, smell, taste, vision, and hearing. (4) Its sensitive and adaptive mechanisms for the regulation of variations in the blood supply and sweat secretion make the skin an organ of dominating importance in relation to the regulation of bodily temperature. (5) The mammary glands are specialized organs of the skin for the secretion of milk. (6) The hair and the nails are modifications of the skin.

The excretory functions of the skin are performed by the sebaceous glands and the sweat glands and by the cytomorphosis of the skin cells.

The sebaceous glands.—The sebaceous glands are found distributed over the entire cutaneous surface. Each gland is usually connected to the sheath of a hair. They vary in size from 0.2 to 2.2 mm. The largest of the sebaceous glands are found in the skin of the nose where the opening of the gland duct may be large enough to be seen without the aid of a magnifying glass. The secretions from these tiny glands are composed chiefly of an oily material containing the débris of degenerated dead cells. This secretion is called sebum. On exposure to the air it hardens and becomes cheesy. Sebum contains all the chemicals that a tissue cell contains. The total amount of this secretion is insignificant. The cerumen or ear wax found in the external canals of the ears, the smegma that forms about the prepuce, and the vernix caseosa of the newly born infant are special modifications of sebum. A commercial product called lanolin is made out of the sebum extracted from the wool of sheep. Sebum may be noted in the comedones (blackheads) and in the papules (pimples) that appear at times on the face. These facial blemishes are due to the closure of the ducts of sebaceous glands. The retained sebum becomes

evident as a comedone or a papule. The sebaceous glands attain their maximum development at puberty. This is, then, naturally, a period in which comedones, papules, and pustules are more likely to appear on the face and body. These various effects of the retention of sebum in the gland ducts are called acne.

The ducts of the sebaceous glands open into the hair follicles so that the sebum that is excreted serves to oil the hair and the surface of the skin around the hair. By this means the hair of the scalp and the lanugo hairs of the skin are kept soft and preserved from brittleness and the skin itself is softened. Because of its oiliness, sebum retards the saturation of hair with water and retards the wetting of the skin. The oily surface of the body has a further advantage in reducing the loss of bodily heat.

The sweat glands.—The sweat glands are long in comparison with the sebaceous glands. It is stated that a sweat gland is, on the average, three millimeters long and that its duct is one millimeter long. The largest sweat glands are found in the armpits, where their coiled glandular parts may be thirty millimeters long. The external opening of the gland duct is called a pore. The pores of the skin may be easily seen by the naked eye.

The sweat glands are found on practically the entire cutaneous surface, occurring in the greatest numbers on the palms of the hands and the soles of the feet. There are said to be two millions of these glands in the skin of the normal average adult. The total length of the sweat glands of the average mature person is more than four miles.

The secretion of sweat varies under the influence of changes in the temperature and humidity of the surrounding air. It is also influenced by certain emotions and by work. It is said that the average quantity of sweat given off as insensible perspiration in twenty-four hours amounts to seven hundred or eight hundred grams. Ninety-nine per cent or more of this amount is water.

Sweat is usually acid. The sweat that comes because of muscular activity is not so acid as the sweat that is induced by heat. The solid matter in sweat has a complicated chemical content. It is known to contain urea, uric acid, creatinin, aromatic oxyacids, ethereal sulphates of phenol and skatol, serin, and albumin, when sweating is profuse.

Under the influence of muscular activity, extreme heat, dyspnea, strong emotions (fear), and various drugs, sweating may

be increased. The common influences that increase sweating are external temperature and muscular exercise. The increase from any of these influences may be very great. Sweating is decreased by lower temperature, emotional conditions, inactivity, fever, and certain drugs.

Physiological experimentation has proved that sweating is the product of nervous and psychic secretions. The psychic secretion described in connection with the physiology of digestion was called an enjoyment secretion. The psychic secretion of sweat might well be called a fear secretion. With the average adult, we have twelve or thirteen square feet of skin surface furnished with about 170,000 sweat glands for each square foot. Each gland is supplied with a network of blood capillaries and lymph capillaries, and the secretory cells of each gland are controlled by nervous mechanisms connecting them with the central nervous system. The nerve centers in the cord (and perhaps the brain) that control sweating respond to sensations (afferent nervous impulses) that come in from the surface of the skin, or from sensory nerve organs deeper in the structure of the skin. Sensations reach these centers also from the complicated nervous and glandular mechanisms that are responsible for emotional states such as fear, terror, and embarrassment.

The sweating of nausea is nearly related to these sources of sensations. In addition it is possible that chemical bodies carried in the blood may directly stimulate the nerve cells in the sweat centers. These circulating chemical bodies may originate in the wear and tear of working activities in remote muscle fibers or they may come from drugs.

These are the avenues and lines of reflex activity whereby muscular contraction, heat, dyspnea, emotions, and various drugs may stimulate the sweat glands to increase the amount of water and solids they secrete from their blood capillaries and the amount of these secretions that they excrete through their pores in the skin as sweat.

The surface cells of the skin are lifeless cells that have been produced in and pushed out from the deeper layers of living skin cells. As the live cells of the true skin grow old they deteriorate and die. New cells are formed and push the older cells to the surface while they are dying. The old dead cells are finally rubbed off as fine, soft, thin particles called desquamations or exfoliations.

The nails of the fingers and toes are also continually growing out from the live cells at their bases or roots. It is said that a hair lives for 1,600 days and then is replaced by a new hair. During this time each hair grows longer just as the nails do, by having the new live cells in its root push the old dying and dead cells on and out of the way. This process of cell birth, growth, degeneration and death is called cytomorphosis. It is characteristic of all living things.

The large intestine.—The large intestine is an excretory organ. It is about five feet long and is approximately one-fifth the whole length of the intestinal canal. Its diameter varies in different regions from one and one-half inches to three inches. The contents of the large intestine are called feces. The feces are composed of rejected foodstuffs, indigestible material eaten with the food, water, secretions from the intestinal glands and from the walls of the large and small intestine, secretions and excretions from the liver, dead cells and tissues from the cytomorphosis of the epithelium lining the intestinal canal, and products of bacterial action in the large intestine.

With a diet largely of meat, the feces are small in amount, dense and dark in color. The putrefactive odor is likely to be disagreeable. On the mixed diet the quantity of the feces will be larger and softer, the color lighter, and the odor less. With a vegetable diet the amount of the feces is much larger, the color still lighter, and the odor much less.

On a mixed diet the daily excretion of feces will weigh about 170 grams. This amount is, however, very variable. On a vegetable diet the weight may go up to 400 or 500 grams.

Along with the solid matter and water in the feces, there are commonly certain gases that arise mostly from the saprophytic action of bacteria on the proteins in the feces. These gases are CH_4, CO_2, HN, and H_2S.

Defecation is the term applied to the act of expelling the feces from the large intestine. Infrequent and inadequate defecation leads to an accumulation of feces in the large intestine. We call this condition constipation. In another chapter we shall discuss the effects of constipation. It is sufficient here to state that constipation is accompanied by an absorption, through the walls of the large intestine, of larger amounts of putrefactive and other irritating and poisonous chemical products. Reference has been

made above to the absorption of indol, skatol, and phenol from the large intestine.

The importance of regular habits of defecation, emptying the lower bowel adequately, every day, should be emphasized here. Regular, open, free movements of the bowels are influential factors of great importance in constructive hygiene.

The excretory functions of the uterus.—There is a period in the life of every normal woman, lasting from puberty (age thirteen to fifteen in temperate climates) to the menopause (age forty-five to forty-eight) in which there is regularly every twenty-eight days a bloody discharge from the *uterus.* This discharge is known as the menstrual fluid. It is formed of cast-off cellular structures from the inner surface of the uterus and is mixed with blood and mucus.

Menstruation involves the following stages: (*a*) Stage of congestion of the uterus and other internal reproductive organs, four or five days. (*b*) Stage of desquamation and hemorrhage from the inner surface of the uterus, four days. (*c*) Stage of regeneration and repair of the inner surface of the uterus, seven days. (*d*) State of rest, twelve days. Unless interrupted by pregnancy or by some abnormal influence, these stages occur once every four weeks for approximately thirty-three years in the life of every normal woman.

Menstruation is dependent upon the formation of ova. At birth, the ovaries contain from 100,000 to 800,000 primordial follicles. Some of these follicles develop with the growth of the individual and begin to mature at puberty. Not all the primordial follicles mature into ova (at the age of 18 there are from 35,000 to 70,000 follicles). From puberty to the menopause one or more follicles mature into ova or egg-cells during each period of four weeks. Ovulation probably occurs at the end of menstruation. A total of 2,000 ova may mature during a period of thirty years.

If the ovaries are removed, menstruation stops. If an ovary or part of an ovary is transplanted into a woman whose menstrual periods have ceased because of the removal of her ovaries, the new ovarian tissue will re-establish menstruation. From these and other facts, it is deduced that the ovaries form an internal secretion which is carried to the uterus by the blood and lymph, and that this internal secretion stimulates the tissues of the uterus, thus causing them to grow. This stimulation is regarded as a prepara-

tion of the uterus for the reception of the fertilized ovum. If fertilization does not take place or the fertilized ovum does not reach the interior of the uterus and become attached to the uterine wall, the old inner surface of the uterus is cast off, in whole or in part, thus forming the menstrual flow which we have classed here as an external excretion. The preparation of the uterine wall is repeated after a resting period of twelve days.

CHAPTER XV

PHYSICAL EXERCISE: AN ESSENTIAL PRINCIPLE OF CONSTRUCTIVE HYGIENE—PRIMARILY A PRINCIPLE OF CONSTRUCTIVE SOMATIC HYGIENE

Voluntary and involuntary activities.—All the activities of the human body may be classified as voluntary or involuntary activities. All the physiological functions that produce those activities may be classified as voluntary or involuntary functions. And all the organs of the body may be classified as voluntary or involuntary organs.

A voluntary activity and the organs and functions that produce that activity are largely under the control of the will. Most of the organs of the body are involuntary. Their functions may be influenced voluntarily and indirectly, for better or for worse, but they are not directly subject to the will. The heart beats and the blood circulates with no direct regard for our wishes. By no effort of the will can one stop the contraction of his heart, the flow of his blood, the respiratory activity of his lungs, or the digestive processes of his alimentary tract. The sensory nervous system brings in sensations of pressure, temperature, pain, sound, light, taste, and smell, in response to effective stimuli, independently of the will. We may only seek the pleasant and comfortable and avoid the distressing. Once within the range of particular stimuli, our sense organs must respond. Very few of us could starve ourselves while food is available. Having once swallowed it, food is no longer under our direct control. We may select the food we desire. We may be careful how we eat and see to it that all our controllable influences are favorable, but, once swallowed, the bolus belongs to the digestive organs that it reaches.

Its onward progress, its digestion, absorption, systemic distribution, utilization by the tissues, and excretion as rejections and wastes are all automatic and involuntary. All the internal secretions are independent of the will. We may voluntarily help or hinder, but we cannot control. Oögenesis, spermatogenesis, and the manufacture of blood-cells are other examples of activities that go on continually with no direction or control from the will.

The only organs that are directly under the control of the will are the voluntary muscles, the voluntary nerve centers, and the

cerebral centers, whatever they are, that constitute the conscious mind. By means of these psychic, nervous, and muscular mechanisms man is enabled to adapt himself to his surroundings more successfully than any other animal. The development of the vol-

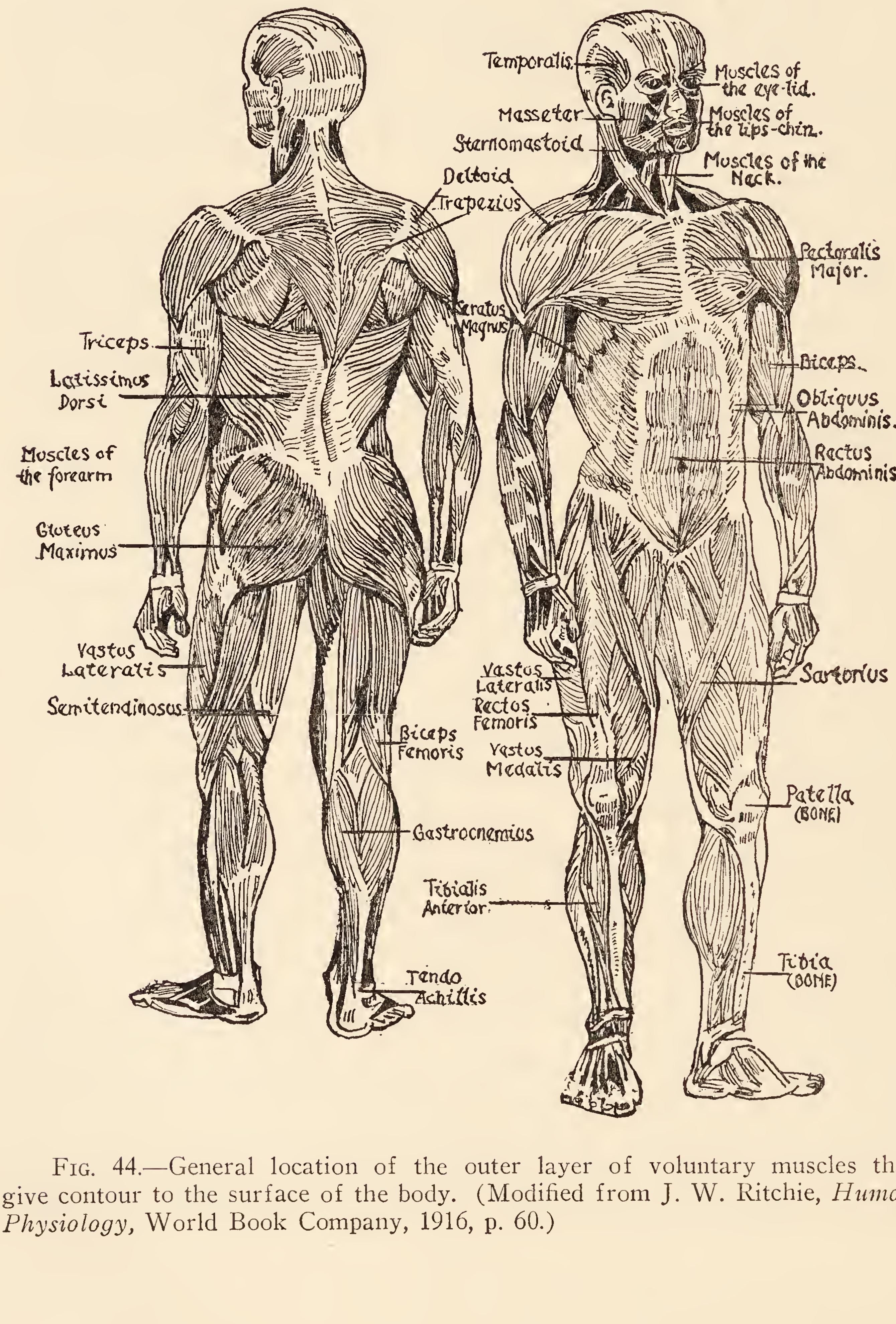


Fig. 44.—General location of the outer layer of voluntary muscles that give contour to the surface of the body. (Modified from J. W. Ritchie, *Human Physiology,* World Book Company, 1916, p. 60.)

untary muscular system has been an essential accompaniment of and cause of the development of the mind. The activities of the voluntary muscular system are described as labor, work, physical activity, physical exercise, active play, and athletics. The term physical exercise covers all these terms. Man's intellectual progress in the slow scheme of evolution has been made possible by the exercise of his psycho-neuro-muscular machinery.

Function of exercise.—The physiology of the muscle-cell explains the constructive values of physical exercise. The muscle-cell is responsible for muscular contraction. Physical exercise is a product of the contraction of muscle-cells. Contractivity is characteristic of all undifferentiated protoplasms; but the highest development of contractivity is found in the muscle-cell.

Muscle-cells are commonly called muscle fibers. There are two main varieties of muscle fibers. There are smooth or plain fibers, and striated fibers. The smooth fibers constitute the smooth or plain muscles that are found in the walls of hollow viscera such as the stomach, the intestines, the arteries, the bladder, and the uterus. Smooth muscles are found, too, in flattish sheets, like the diaphragm. Striated muscle fibers are found in the muscles of the heart and in the muscles that move the bones of the skeleton. These fibers are called smooth or striated because of their appearance under the microscope. The striated fibers have fine transverse stripes. The smooth fibers have no stripes.

There are three main forms of muscle tissue: the smooth muscles, the cardiac muscles, and the skeletal muscles. The smooth muscles are characterized by slow, long-continued contractions. They are involuntary. The cardiac muscles are responsible for the beat of the heart. They too are involuntary. The skeletal muscles constitute the voluntary musculature. They are the muscles with which we are concerned in this chapter. A striated muscle fiber is commonly three or four centimeters long, but some are much longer. These fibers vary from 0.01 mm. to 0.1 mm. in diameter. It is obvious that a muscle like the biceps must contain a very large number of fibers, probably six or seven hundred thousand.

A striated muscle fiber is a giant tissue cell. It contains several nuclei. It contains also a number of longitudinal fibrils imbedded in a semi-fluid substance called sarcoplasm. These fibrils are the contractile elements in the muscle-cell.

When a muscle-cell contracts it uses chemical materials that have been brought to it by the blood. These materials were discussed in an earlier chapter. The nature of the chemical changes involved in the contraction of muscle is not understood. We know that carbon compounds are used, that lactic acid, carbon dioxide, and water are produced, and that heat is evolved. These changes make it necessary that new carbon compounds be made available if

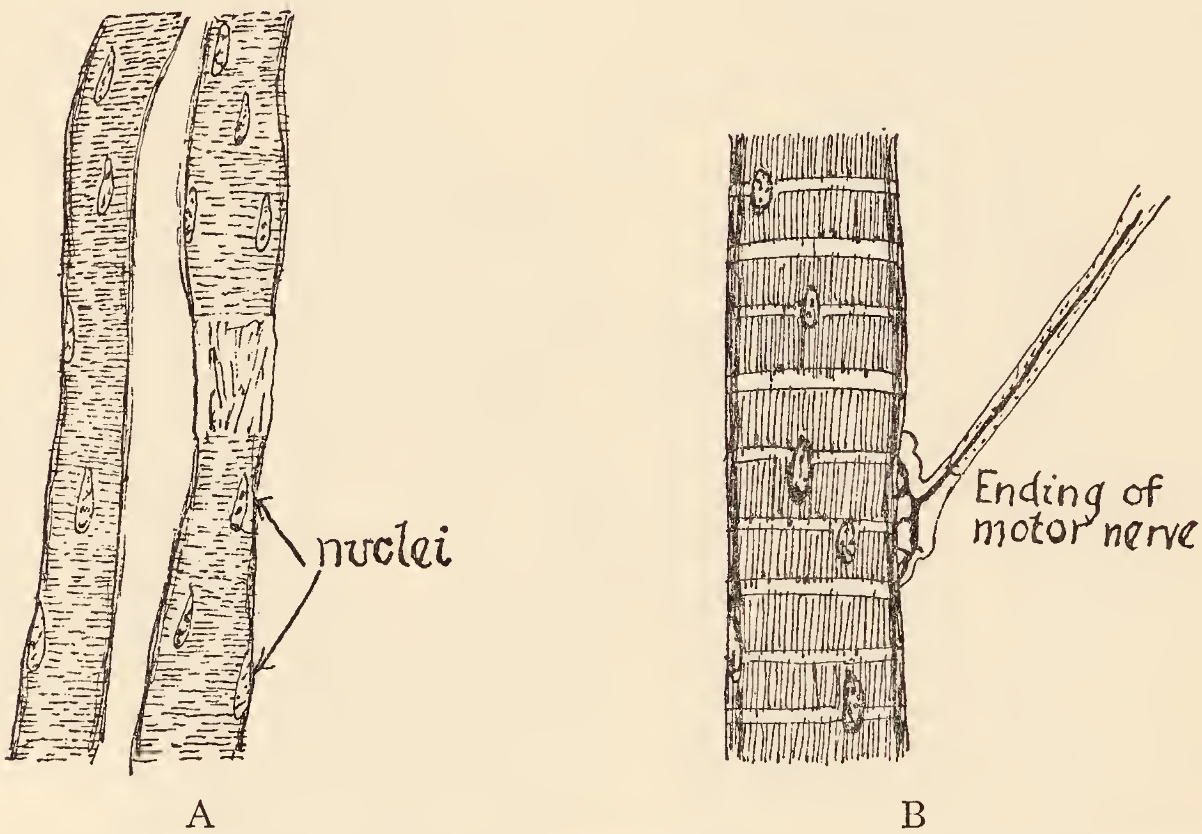


FIG. 45.—Striped muscle fibers, much enlarged; *A,* two fibers showing nuclei; *B,* greatly enlarged muscle fiber containing a nerve ending.

the muscle fiber is to furnish any more contractions. They also make it necessary that the products of these changes be removed.

It is obvious that muscle contraction involves the contraction of an enormous number of muscle fibers, every one of which depends upon its own blood capillaries for a supply of new chemical material and for the removal of the material it has used.

Microscopic examination of the striated muscle fibers shows that every one of them has a nerve ending. The voluntary contraction of a voluntary muscle is produced by the distribution of nervous impulses from the central nervous system to every muscle fiber that takes part in the shortening of the muscle.

Muscles probably never work singly. All our movements are produced by the co-ordinated and adjusted contractions of groups

of muscles acting on the bony levers of the skeleton. Physical exercise is therefore an activity in which many groups of muscle-cells, nerve-cells, and blood capillaries take part. The need for a rapid increase in chemical supplies and for a rapid removal of rejections and wastes becomes more and more urgent in proportion to the vigor and duration of the physical exercise. The oxygen intake and the carbon-dioxide output may be increased ten or twelvefold over the normal respiratory exchange. The output of blood from each ventricle of the heart may be increased ten or twelvefold. The pulse rate rises in proportion. The heart rate will slowly increase with sustained exercise. It is said that for a short period of time, the muscular work, the respiratory exchange, and the delivery of blood may be increased 600 per cent over the resting average. By training, this margin of increase may be enlarged.

The effects of physical exercise may be immediate and temporary or they may be cumulative and, in time, relatively permanent.

Temporary effects.—The temporary effects of physical exercise may be listed as follows: (1) An increased transformation by the muscle-cells of potential into kinetic energy (and heat), using the local tissue carbon compounds and oxygen for the purpose. (2) An increase in the products that accompany this transformation, viz., lactic acid, carbon dioxide, and heat. (3) An increase in the supply of arterial blood and lymph to the active muscle-cells. The active capillary area in the muscles may be increased from forty to one hundredfold. (4) An increase in the drainage of venous blood and lymph from the active muscles. (5) An increase in the heart rate and the quantity and rate of the blood flow into the heart and from the heart. (6) An increase in the rate of respiration and in the amount of oxygen and carbon dioxide exchanged. This means an increase in the supply of oxygen to the blood for the contracting muscle-cells and an increase in the rapidity of the removal of carbon dioxide from the capillaries of the contracting cells and its more rapid external excretion from the blood stream. (7) An increased secretion of sweat. (8) An increase in the blood circulation of the skin. (9) An increase in the cerebral circulation, bringing a larger blood supply to the motor areas of the brain. (10) A decrease in the blood supply of the alimentary tract, making that blood supply available to the muscle-cells that are being exercised. (11) A feeling of fatigue and, if the exercise is too violent and prolonged, a state

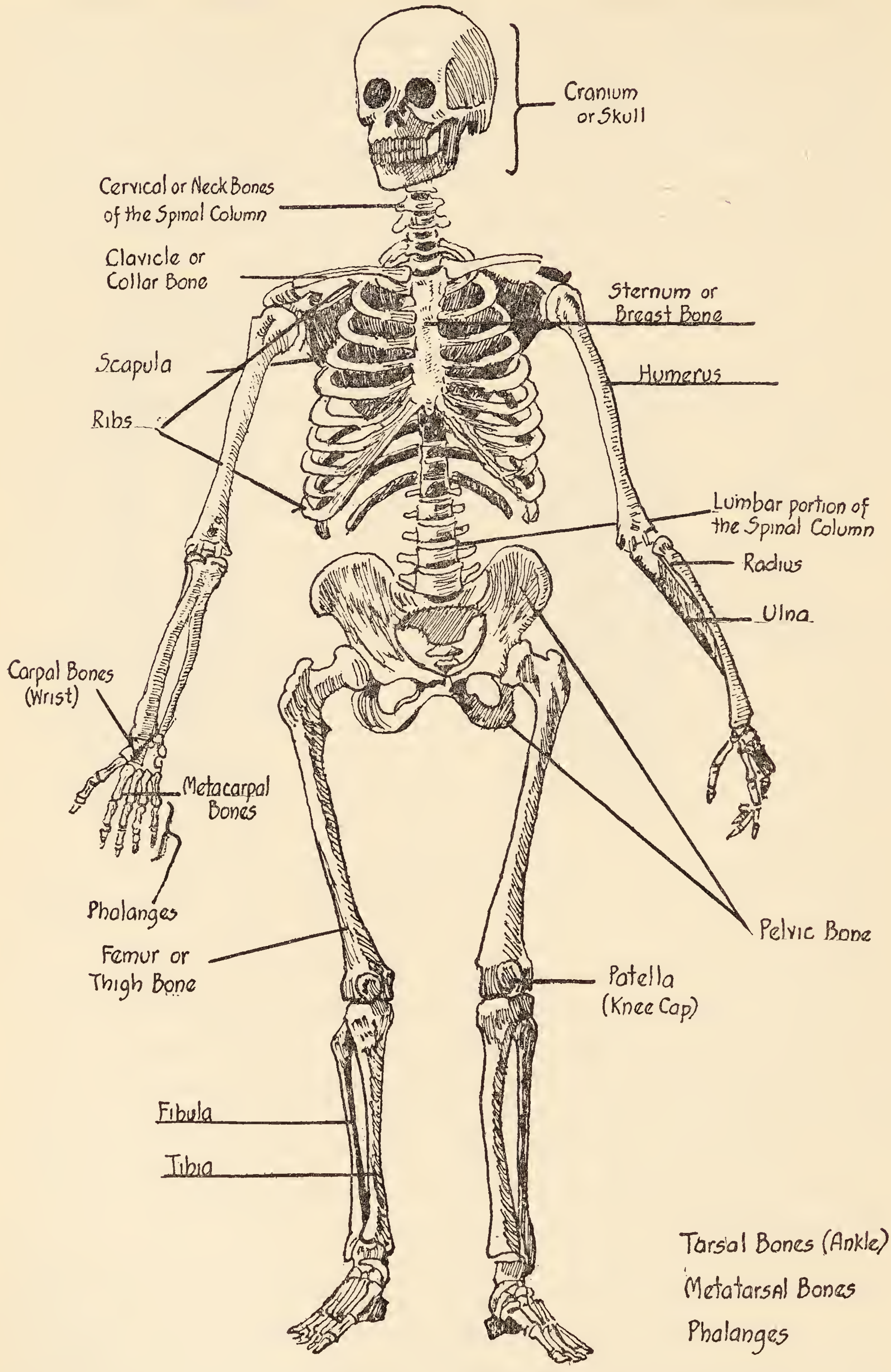


FIG. 46.—The skeleton, showing the bony framework of the body.

of exhaustion. (12) After a few minutes of rest, a good bath, a cold or cool shower, and a rub-down with a coarse towel, a feeling of buoyancy and exhilaration that is very satisfying. (13) An increase of appetite and a desire for food and water. (14) Easier sleep and more perfect rest after vigorous exercise carried out within the strength limitation of the individual.

Permanent effects. — The cumulative and more permanent effects of regular physical exercise may be listed as follows: (1) Larger and stronger muscles, with a more enduring power of contraction. This effect is due to an increase in the diameter of the individual muscle fibers. (2) A more orderly co-ordination of the muscles. (3) A better nervous control over the muscles. (4) A stronger heart heat. The muscle fibers of the heart increase in diameter; the irritability of the heart is lessened so that it meets the demands of the active muscles and of the lungs for more blood without the excess of muscular excitement that is characteristic of a heart out of condition and unused to exercise. (5) A more orderly and a more enduring muscular control of respiration. The "wind gets better"; respiratory fatigue is postponed. (6) The organs of external excretion, the kidneys, the lungs, the skin, and the bowels are trained and conditioned to remove effectively the internal excretions brought to them by the blood; the greater regularity and effectiveness of the movements of the bowels and the clearer and more resilient condition of the skin are particularly noteworthy as effects of regular exercise. (7) Vigorous but rational exercise in the period of childhood and youth is an effective contributory and stimulating influence on physical growth and organic development; with plenty of physical exercise, the child gains an appetite that urges and searches for the food that the growing, developing cells of the child's whole physical being must have if their growth and developmental possibilities are to be fully achieved; under-nutrition or malnutrition in this period may be due to a lack of appetite rather than to a lack of available food. (8) The tone of the muscles is improved. An exercised muscle not only has the power of contraction, it maintains also a state of slight tension that is called tone; a flabby, flaccid, and soft muscle lacks tone. A muscle that is regularly exercised is not only better nourished and stronger, but even at rest it is firm and resilient. When the nerves that connect a muscle with the central nervous system are cut or otherwise de-

stroyed the muscle is paralyzed. It can no longer be made to contract by an effort of the will. In addition it loses its tone. It may be exercised by passive motion, electrical stimulation, and massage, but none of these influences will restore its tone. From these and other facts we know that the nutrition of the muscles as shown by their tone depends upon the integrity of their nervous connections. This is added evidence that exercise of a muscle is exercise of the nervous elements that supply the muscle.

The health of a muscle is in part a product of its exercise. The health of the body is in part a product of the health of its muscles. A review of the immediate and cumulative effects of physical exercise brings out two very important general facts concerning our control over the health of our organs.

1. It is evident that we have an extensive, direct control over the hygiene of the skeletal muscles. These muscles represent 41 per cent of the body weight. Rational physical exercise therefore enables us directly to improve and maintain the health of a great group of organs that constitute 41 per cent of the total weight of all the organs of the body. A neglect of physical exercise is a neglect that affects directly the hygiene and therefore the health welfare of more than two-fifths of the body. It is obvious that this direct and large dependence of the skeletal muscles upon our voluntary control brings us a responsibility and an obligation in relation to the constructive hygiene of those muscles.

2. It is evident that our extensive and direct control over the constructive hygiene of the skeletal muscles gives us an indirect and hardly less extensive or complete control over the constructive hygiene of all the other organs of the body. By means of the direct exercise of 41 per cent of the body weight, we induce an exercise of the heart and lungs, 2 per cent; the skin, 7 per cent; the blood circulation, 7 per cent; the skeleton, 16 per cent; the digestive tract, 7 per cent; and the brain, 2 per cent. We may even influence the fat of the body, representing 18 per cent of the total weight. An organ that is exercised grows and develops. It gains health. An organ that is not used atrophies. This is a well-established law of physiology. (See Fig. 45 for muscle, and Fig. 46 for skeleton.)

Regulation of exercise.—These relations between physical exercise and the organic constituents of the body are largely re-

sponsible for the evolutionary history of the human race and for the health success or failure of the individual. Our control over the skeletal muscles offers an opportunity for a direct and powerful influence upon the constructive hygiene of those muscles and an indirect and hardly less powerful influence upon the constructive hygiene of all other organs. Rational physical exercise is, therefore, an essential factor in constructive hygiene. It is a basic health habit. Physical exercise in some form and amount is necessary to the health of the muscles and to the health of the individual. The type and quantity should be adjusted to fit the age, sex, and physical condition of the individual.

Exercise is better taken in the middle or latter part of the morning or in the latter part of the afternoon. It should not be taken within an hour after meals. Outdoor exercise is better than indoor exercise. Exercise of many muscles is better than exercise of a few muscles, and the benefits of the exercise of the big muscles are in proportion greater than those of the small muscles.

Exercise should be interesting and regular. It should be a daily habit. The activity should lead to sweating and be followed by a cleansing bath and a cold or cool shower. The temperature of the bath should be adjusted, however, to suit the reaction of the individual. Some people cannot stand cold water.

Children require a great deal of big-muscle exercise. They will get what they need if they are given opportunity to satisfy their natural hunger for play. The physical exercise of the running, jumping, climbing, tugging, dancing muscles of children is inseparably a part of their play life. The adult responsibility and obligation is to see that the child has a rich opportunity for wholesome, vigorous, safeguarded play.

The physical exercise of the adult should be regulated to fit his strength, previous experience, and physical condition. After reaching middle age, exercise in amounts and severities that produce labored breathing and a rapid heart rate should be avoided.

CHAPTER XVI

PLAY: AN ESSENTIAL PRINCIPLE OF CONSTRUCTIVE HYGIENE —PRIMARILY A PRINCIPLE OF CONSTRUCTIVE MENTAL HYGIENE AND THE CONSTRUCTIVE HYGIENE OF SOCIAL PERSONALITY

Interdependence of mind and body.—The preceding chapter on physical exercise gave evidence of the dependence of the skeletal muscles and the nervous system each upon the other. It gave evidence too of an interdependence between the nervous system and all other systems of the body. It is impossible for one to exist without the other. Human life and health are products of this mutual interlocking dependence. Health and life may be injured or destroyed by damaging interference with this mutually interdependent relationship. Nerve health and mental health and other products of nerve health are dependent on bodily health, and the reverse is equally true. Nevertheless, it is practical and reasonable to consider the physiology and hygiene of the nervous system separately, just as it is reasonable and practical to consider the physiology and hygiene of the skeletal muscles, or any other system of organs, separately.

The nervous system.—The nervous system may be described as consisting of the brain, the spinal cord, and the nerves that connect the brain and spinal cord with all the organs and tissues of the body. The brain and cord form the central nervous system or cerebro-spinal system. The nerves constitute the peripheral nervous system and the sympathetic nervous system. The sympathetic nervous system includes also the autonomic nervous system. These systems are not separate and distinct. They are all intimately parts of a single great system of nerves concerned with the reception of information derived from impulses coming from external stimuli and with the development of consequent adaptive reactions in the cells and organs of the body.

The neurone.—The nerve-cell or neurone is the physical basis of the nervous system. The physiology and hygiene of the nervous system is a product of the physiology and the hygiene of the nerve-cells of which the nervous system is constituted. Nerve-cells vary in size and in shape. They are of microscopic size. The typical parts of a nerve-cell are: (1) a cell body; (2) one or more

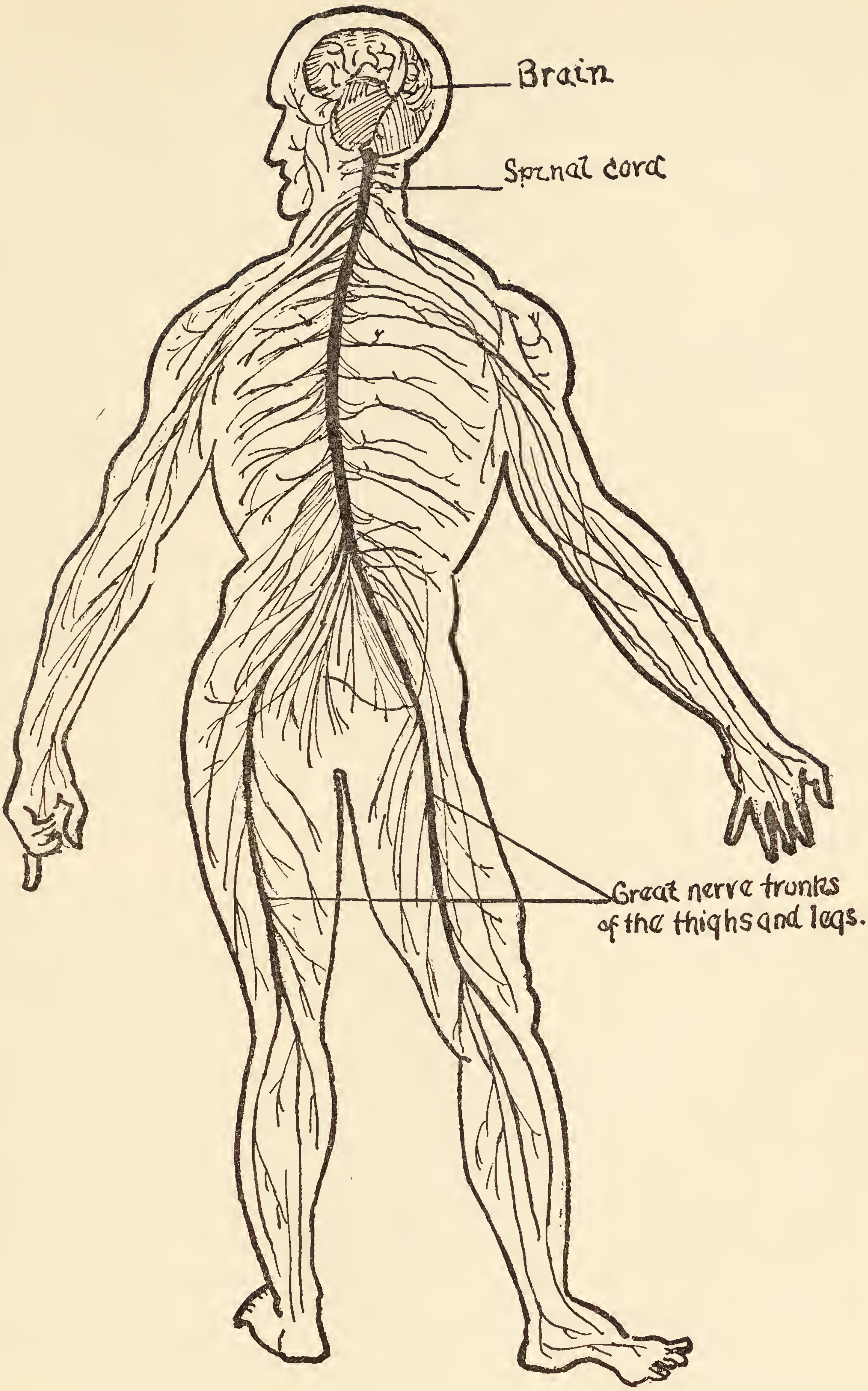


Fig. 47.—The general nervous system, showing the brain, the spinal cord, and the peripheral nerves. (After Martin in *Martin's Human Body.*)

dendrites; and (3) an axis-cylinder process. The cell body is irregular in shape and contains a nucleus and other special anatomical parts. The cell body varies in diameter, roughly, from one two-hundred-and-fiftieth to one thirty-five-hundredth of an inch. The irregularity in the shape of the nerve-cell is due to the fact that the body of the cell is extended into one or more dendrites and an axis-cylinder process. These projections and elongations are parts of the cell. They are not added separate growths. A dendrite is a short, rapidly narrowing elongation of the body of a nerve-cell. It divides into a number of small branchings like the many branches and twigs of a little tree. The axis-cylinder process is sometimes called an axon or a neurite. It is a prolongation of the nerve-cell. The shorter axis-cylinder process may have a length of one-twentieth of an inch. The longer axis-cylinder processes may reach an extraordinary length for microscopic structures. The axis-cylinder processes that form motor nerves connecting the spinal cord with the muscles of the toes may be three feet or more in length. The axis-cylinder process ends in a special terminal, usually a many-parted branching like that of a bush, called the terminal arborization. Fine lateral fiber processes are given off at right angles from the axis-cylinder process. They are called collaterals of the axis-cylinder process. The axis-cylinder process varies in diameter from one fifteen-hundredth of an inch to one hundred-thousandth of an inch.

The cell body, the dendrites, and the axis-cylinder process taken all together form the nerve-cell. One must not think of the thickened body part as the cell and the projections and prolongations as separate from the cell. The nerve-cell is commonly called a "neurone." (See Figs. 47 to 50 for nervous system and nerves.)

Functions of the neurone.—The nerve-cell or neurone has the basic functions of all tissue cells. It absorbs its chemical needs from the lymph that surrounds it. It builds its own structure, nucleus, and cytoplasm, repairs its structural damages and losses, produces its own energy transformations, manufactures its own special functional products, and eliminates its own wastes. It is dependent upon other cells for its chemical income and for the removal of its chemical outcome. And it contributes its own functional service to the body as a whole, making possible the activity, health, and life of all the cells of the body.

The neurone possesses also specialized functions of irritability

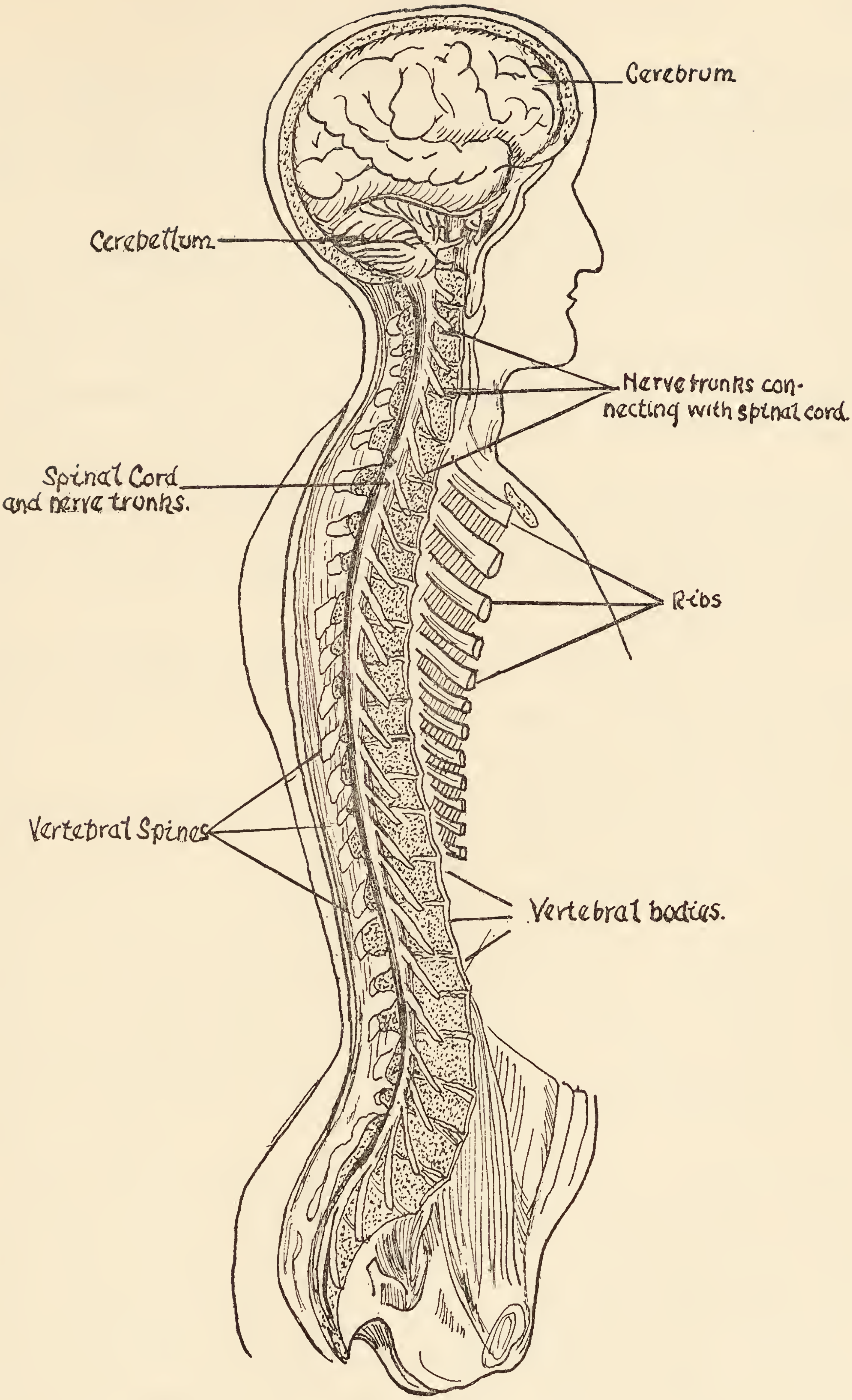


FIG. 48.—General view of central nervous system, or cerebro-spinal axis. (After Bourgery, in *Anatomie du Système Nerveux,* by A. Van Gehuchten, Louvain, 1900, p. 2.)

and conductivity. These two functions are more highly and specially developed in the neurone than in any other type of cell.

In addition to these common functions that are present in all living tissue cells, the neurone exhibits two special functions that characterize nervous tissues.

The first special function of the neurone is the production and transmission of *nervous impulses.* The neurone is a generator and conductor of nervous impulses. The delicate irritability of the neurone makes the neurone exquisitely sensitive to external stimuli. Stimulation of this irritability is followed by the production of nervous impulses. Normally, stimulation of the neurone is effected through its dendrites. There are certain neurones the cell bodies of which appear to be in contact with the end branchings of axis-cylinder processes of other neurones. Such cell bodies would then receive stimuli from those end processes directly and not by way of their dendrites.

Only under abnormal conditions are stimuli applied to other regions of the neurone. The common external stimuli that affect the irritability of neurones are light, sound, odor, flavor, temperature, touch, and trauma (pressure).

Various specializations of other tissue cells may be cited here because of their selective relation to the reception of external stimuli by the neurones. For instance, the eye is a receptor organ made up of a variety of tissue cells specialized for the purpose of selecting light waves and rejecting other stimuli such as sound, odor, and taste. The irritable neurone endings in the retina of the eye, therefore, receive stimuli only from light waves that have been focused on the retina by the camera-like apparatus of the eye. The stimulation of these irritable neurone endings produces nervous impulses that are conducted along the length of the neurone inward to the neurones in the optic paths or areas of the brain. The ear is a receptor organ concerned with the selective admission of sound waves for the stimulation of the neurones of hearing. The organs of Corti in the inner ear receive sound waves from the middle and outer ears and are not subject to other forms of stimuli. The irritable neurone endings, the dendrites, in the organs of Corti are stimulated by these sound waves and produce nerve impulses in these neurones that are conducted along the length of the neurones in the auditory nerve to their axis-cylinder process-endings in the auditory centers of the brain.

There are receptor organs specialized in the nose for the selective admission of odor stimuli, receptor organs in the tongue (taste buds) specialized to sort out and receive stimuli of taste only, and receptor organs in the skin, some specialized to receive stimuli of touch, some of heat, some of cold, and some of trauma.

Each special type of receptor is affected only by the special sort of stimuli for the reception of which it has been developed. All other kinds of stimuli have no effect.

The neurones whose irritabilities are stimulated through one receptor organ are not connected with the other receptor organs, and they conduct their nervous impulses to neurones in but one type of nerve center in the brain.

We have good reason to believe that all nervous impulses are of the same nature. For instance, the nervous impulse conducted by a neurone in the auditory nerve is the same as the nervous impulse conducted by a neurone in the optic nerve. The feeling (sensation) of sound is a product of the influence of nervous impulses after they reach the neurones in that part of the brain that is concerned with producing the consciousness of sound. In other words, we do not hear or see or feel outside the brain. There is no consciousness in the ear or the eye or the finger-tips. Neurone connections with these and other receptor organs bring nerve impulses to the brain, which are there transformed into feelings of vision, sound, touch, pain, or other sensation. There is no feeling in the receptor organ. There is no feeling in the receptor neurone. There is no feeling associated with the nerve impulse produced by the stimulation of the dendrites of the receptor neurones. The feelings of sight, hearing, and all other sensations are produced in the brain by the influence of nerve impulses upon the neurones in the brain. These feelings are a part of mind.

The second special function of the neurone is to contribute to the production of mind. The human mind is not an organ. It is an autonomic and voluntaristic government of the behaviors of the tissue cells and organs and of the individual they constitute. Our knowledge of mind has increased enormously in recent years, but even with that increase we know but little about it. The functions of the neurones are essential to the unconscious and conscious mental activity concerned in governing anatomical, physiological, psychological, and social behaviors of the individual.

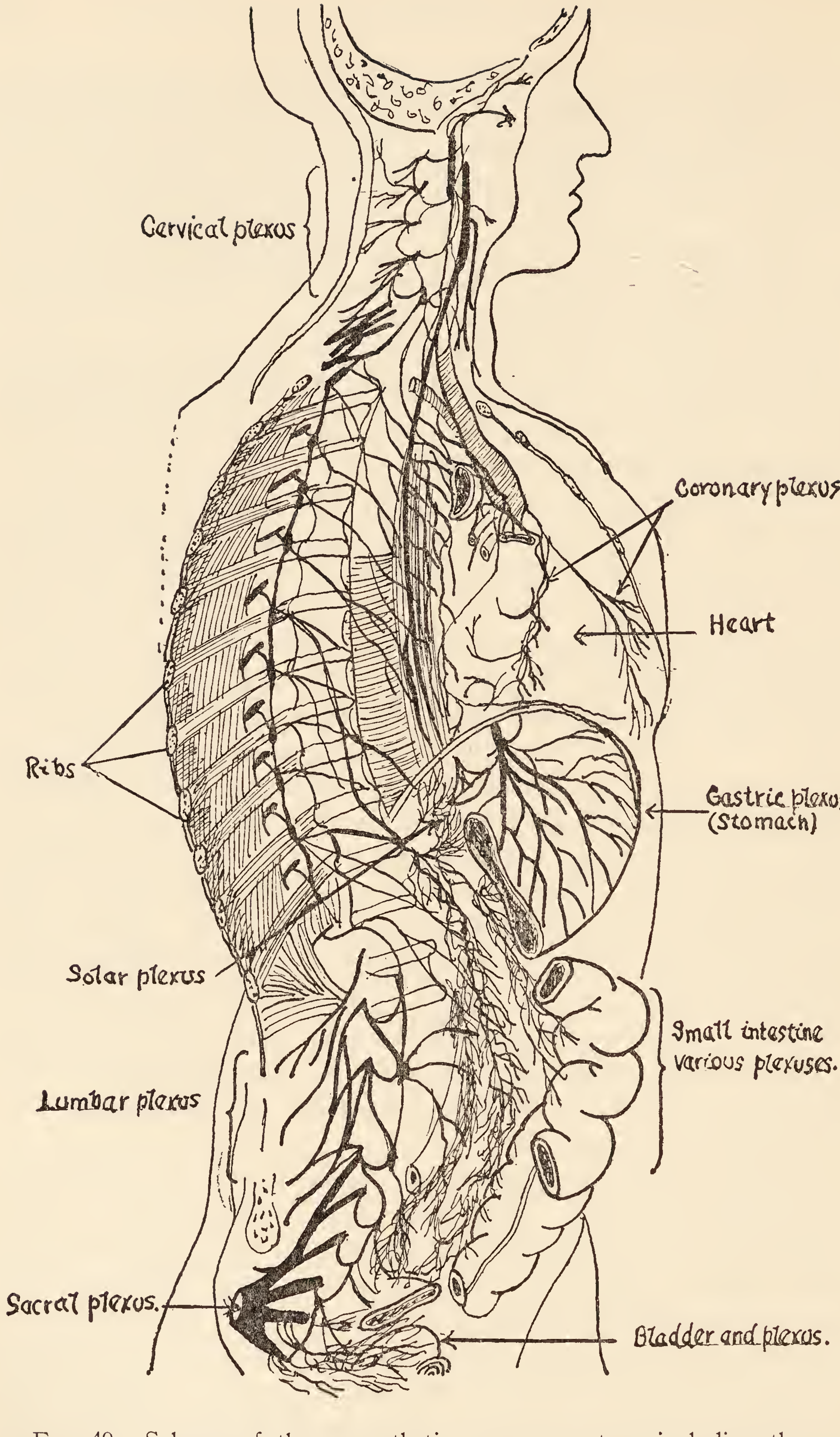


FIG. 49.—Scheme of the sympathetic nervous system, including the autonomic system, showing the chain of ganglia of the right side in heavy black connections with the cerebro-spinal system and the organs of the neck, thorax, abdomen, and pelvis. (After Schwalbe, in *Anatomie du Système Nerveux,* by A. Van Gehuchten, Louvain, 1900, p. 3.)

Every mental process and every mental element out of which mental processes are made is a product of the functional activities of many neurones. The receptor organs of the body are concerned with the selective distribution of external stimuli to appropriate sensory neurones so that the nerve impulses that are generated in those neurones may be conducted to synapses in those regions of the cerebro-spinal system in which nerve impulses are transmuted into the phenomena of mind.

The two special and distinguishing functions of the neurone are, first, the generation of nerve impulses and, second, assistance in the transformation of those impulses into mind.

The neurones of the body may be classified in three groups based upon their conduction or transmission service. These groups are: (1) the afferent nerves or neurones; (2) the efferent nerves or neurones; and (3) the association nerves or neurones. They may be described also as: (1) the sensory nerves, (2) the effector nerves, and (3) the association nerves.

The *afferent nerves* are the nerves that conduct or transmit nervous impulses from the periphery into the central nervous system, that is, into the spinal cord and brain. Anything outside the central nervous system is peripheral or external to that system. Nervous impulses transmitted from the surface of the body or from the internal organs of the body to the cerebro-spinal axis are transmitted by the afferent neurones. Impulses transmitted from the cerebro-spinal axis (brain or spinal cord) to the organs of the body are transmitted by the *efferent neurones.* The impulses that are transmitted from afferent neurone endings in the brain to efferent neurones in the brain are transmitted by connecting neurones called *association neurones* or association fibers or association nerves.

The afferent neurones generate and transmit all the nervous impulses that are stimulated in the dendrites of those neurones by changes in the internal or external environment of the central nervous system. These nervous impulses come from receptor organs in the ears, the eyes, the nose, the mouth, the skin, the muscles, the tendons, the viscera, and all the other organs of the body.

In the light of our present knowledge it appears probable that the association neurones, stimulated by nerve impulses received from the afferent neurones, produce all the mental processes that constitute the highest levels of human mind.

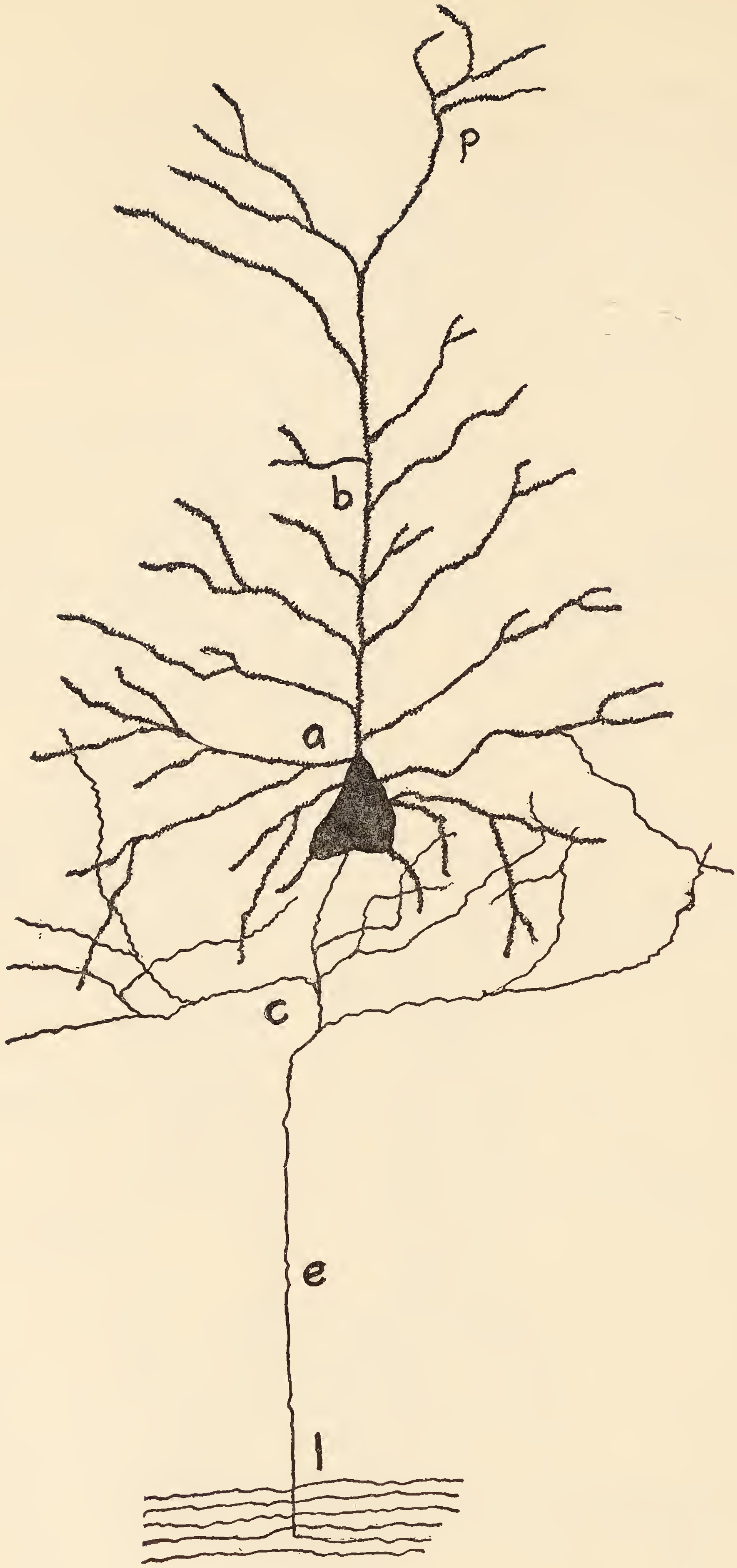


Fig. 50.—A nerve-cell: *a,* cell body; *b,* dendrite and branches; *c,* axone, axis-cylinder process, or neurite with various collateral branches; *e,* continuation of *c,* terminal arborization of axone not shown. (After Raymón y Cajal.)

The efferent neurones transmit nervous impulses from the brain or spinal cord to the cells of muscles, glands, and other organs of the body. These efferent neurone impulses may be immediate reflex or automatic reactions of efferent neurones stimulated directly in the cord by afferent nerve impulses. For example, when one burns his fingers, he withdraws his hand from the flame by a reflex act that is not delayed by waiting for directions from the mind. The efferent nervous impulses may also be voluntary motor impulses transmitted by neurones from the brain under the influence of mind. All our voluntary muscular contractions are stimulated by efferent nervous impulses.

The connection between one neurone and another neurone is a connection by contact, not by continuity. The weight of scientific knowledge at the present time is against the theory that there is a protoplasmic continuity between neurones, though some observers have described fibrils passing from one neurone into another.

A connection by contiguity is shown between the terminal arborization of the axis-cylinder process (i.e., the axon) of one neurone and the branching dendrites of a second neurone. Terminal arborizations of axons about cell-bodies of neurones are noted in certain special nerve cells.

The interlacing of the terminal branchings of an axon with the branchings of a dendrite is called a *synapse*. A considerable major portion of the structure of the brain is made up of these interlacings. It is believed that the events which take place in the synapses of the cortex of the cerebrum when afferent nerve impulses arrive there are responsible for those phenomena of feelings, thoughts, ideas, memories, reason, judgments, etc., that we call mind. There are more than nine billion neurones in the cortex. Each of these neurones participates in the formation of several synapses in the cortex. Each synapse is formed of many terminal, branching, interlacing contacts of dendrites and of axon or collateral arborizations. Therefore some hundreds of billions, probably many hundreds of billions of contacts between neurone terminals form the area in the cortex in which the phenomena of mind are produced.

Neurones probably never function singly. They function in series. A *chain* or path of sensory or afferent neurones united by synapses connect a receptor organ with synapses in the cortex of the cerebrum. A chain or path of neurones connected by synapses

associate the various points and regions of the cortex with each other. A chain or path of efferent neurones connect the synapses in the cortex of the brain with neurones in other parts of the brain and by various routes with cells in the muscles and glands and other organs of the body which are stimulated thereby into action by nerve impulses reaching them from those efferent axis-cylinder processes (i.e., axons) that have contact endings on the cells of those muscles and glands.

The simplest conceivable series of neurones would be made up of one afferent neurone and one efferent neurone united by a synapse. Such a series might occur between a sensory neurone ending in the spinal cord and an efferent neurone beginning in the cord. Such a chain of two neurones would constitute a simple *reflex arc.* There would be no association fibers in such a chain. The brain would not be involved. In such a series the sensory-nerve impulse would be transmitted from the terminal arborization of the afferent axis-cylinder process through a synapse with the branching dendrites of the efferent neurone in the spinal cord. The nerve impulse would then be transmitted to the terminal branchings of the efferent axis-cylinder process and stimulate the cells of the bodily organ on which that process ends. It is not probable that such a simple reflex arc even exists.

If the afferent neurone in such a simple reflex arc were a neurone that transmits nerve impulses stimulated by pain from a pinched finger, for instance, the reflex act withdrawing the finger from the pinch would be the result of an efferent nerve impulse stimulated in the dendrites of a neurone in the cord by the afferent nerve impulse from the finger and transmitted to the muscles of the arm by the efferent neurone. (See Fig. 51.)

It probably never happens that a single series of neurones functions alone. A pinched finger stimulates a number of sensory neurone chains. The consequent efferent reflex nerve impulses are carried, not by one neurone-chain but by a number of neurone-chains that transmit nerve stimuli to many muscle fibers, necessarily in an orderly, co-ordinated manner.

There is probably no such thing in the life of a human being as a simple reflex act involving merely an afferent neurone and an efferent neurone. The nerve experiences of human beings are infinitely complicated. In man each optic nerve trunk contains at least one hundred thousand axis-cylinder processes. There are

from sixteen thousand to twenty thousand auditory end-apparatuses in each ear. Over six hundred and fifty thousand axis-cylinder processes enter the dorsal roots of the spinal cord. There are at least a million axons leaving the cord by way of the ventral roots. At least two million axons enter and leave the cord.

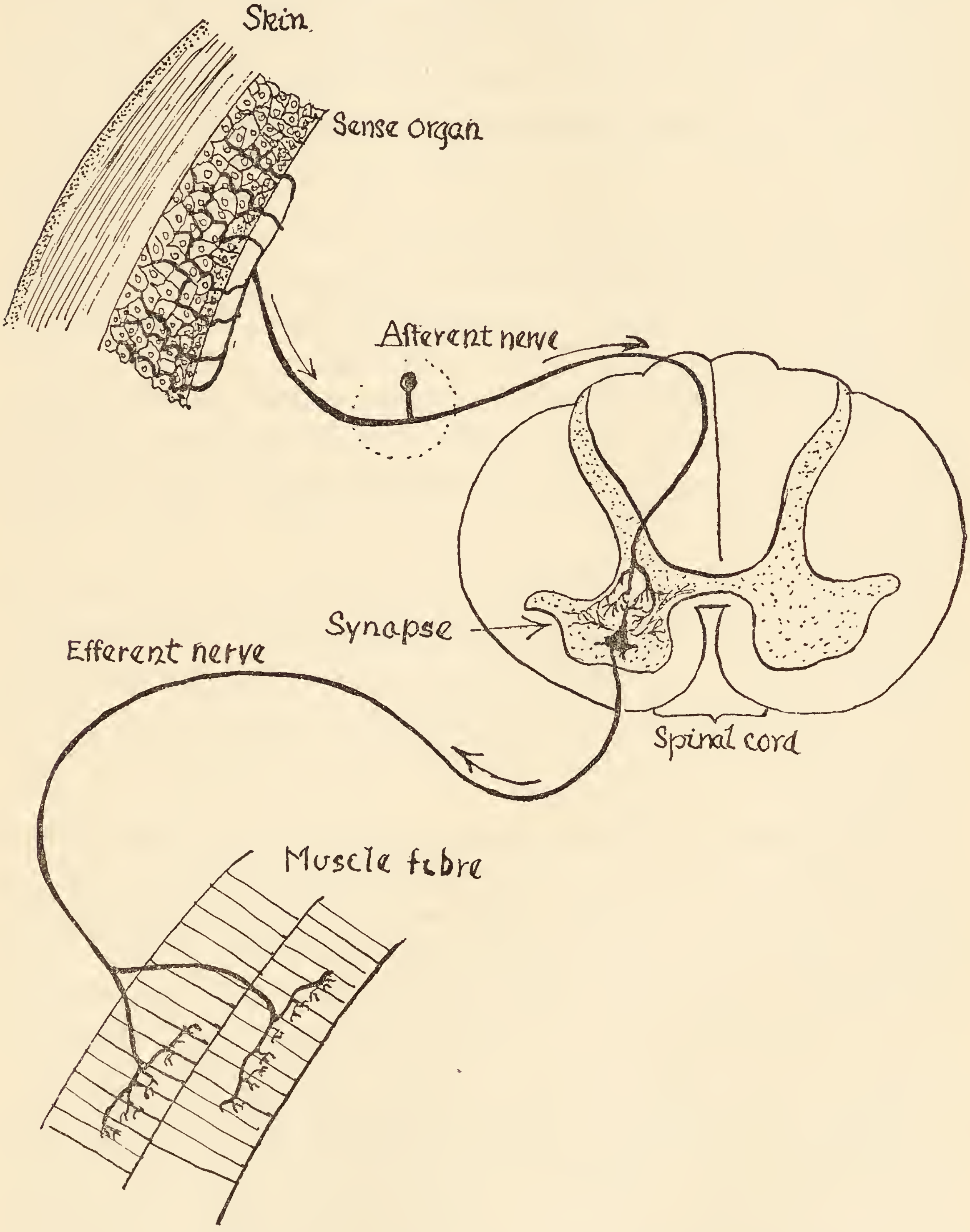


FIG. 51.—Diagram of a simple nerve reflex, illustrating a receptor organ in the skin, an afferent (sensory) neurone, a synapse in the spinal cord, an efferent (motor) neurone, and a nerve-ending in an effector organ (muscle fibers).

". . . . counting at the rate of fifty a minute it would take a man working twelve hours a day over two hundred years, probably over seven hundred years, merely to count the nerve cells of one man."[1]

Relation of the neurone to daily life.—The daily life of the average intelligent individual calls into functional service a large part of this nerve equipment. His varieties and gradations of receptor stimuli must run into many thousands, the use of some of which may be repeated many thousands of times during a single day. There are always many streams of sensory nerve impulses going into the cord and the brain from the eyes, the ears, the nose, the mouth, the skin with its variety of special types of sensory organs, the muscles, the tendons, the heart and circulation, the alimentary tract, the glands of the body, and in fact from all the functioning organs of the body.

Feelings, emotions, moods, thoughts, mental images, memories, impulses, and other varieties of mental activity are constantly present in varying degrees, amounts, and complexities, either in kaleidoscopic procession or in a more orderly and controlled sequence.

And in the normal individual there are always a number of voluntary and involuntary organic motor and other effector activities going on that depend upon nerve action. Every voluntary act and every involuntary act—the digestion of food, the movements of respiration, the regulation of the heart—all involve more or less complicated nerve reflexes.

Development of mind.—At birth, there is no conscious mind. It is estimated that the nerve system of the new-born infant is supplied with thirteen billion undeveloped and partially developed neurones. The prenatal experience does not develop many, even of the lower reflexes and calls for no service from any of the higher neurone associations. All nerve-cells must be developed by use either in the prenatal period or later. The conscious mind is produced by the afferent nervous impulses that establish and strengthen synapses in the cerebro-spinal axis and especially in the cerebral cortex. At birth the average brain weighs about four hundred grams. The average weight doubles within a year and

[1] Edward L. Thorndike, *Elements of Psychology* (A. G. Seiler, 1922), p. 151.

trebles in four or five years. Growth ceases generally in eighteen or twenty years. The average mature brain weighs about fourteen hundred grams. After the age of eighteen, the weight decreases gradually. After the age of sixty, the weight of the brain is likely to decrease rapidly.

The doubling of the weight of the brain in the first year of life and its trebling during the first four or five years are products of the influences of the functional exercise of the neurones of the brain. The exercise of these neurones is possible only as a result of stimulations from nerve impulses transmitted to them by the afferent nerves.

The "mind" of the living germ-cell and the "mind" of the fertilized ovum is sometimes called a "tropic mind." The "mind" of the embryo is sometimes called a "reflex mind." There is no consciousness in these minds. It could be properly urged that these are not complete minds and that there is no complete mind in the newly born child. But the terms tropic mind and reflex mind are useful terms in that they describe a government of movement, secretion, metabolism, mitosis, or other physiological activity in response to mechanical, physical, or chemical stimuli that may occur with or without the service of a nervous system. The conception of "unconscious mind" has gained a firm place in recent psychology. The unconscious mind is thought to contain the inherited mental experiences of the individual and those experiences of early mental life that persist in ideas that may not gain conscious expression.

We may say that the infant appears at birth with all its activities governed by tropism and reflexes. There has been no consciousness, and the appearance of intelligence is delayed for some time. All its activities during the two hundred and eighty days in which it has been developing from a fertilized ovum have been excited by mechanical, physical and chemical stimuli.

Reflexes and tropisms of germ-cells and embryos are seen in the movements of spermatozoa, movements of protoplasm in egg-cells and embryonic cells and cell-masses in the formation of the gastrula, alimentary canal, nervous system, and other organs .... the entire process of development, whether accompanied by visible movements or not, may be regarded as a series of automatic responses to stimuli. When the embryo becomes differentiated to such an extent as to have specialized organs for producing movements, its capacity for making responsive movements to stimuli becomes much increased. In the embryo the rhythmic contrac-

tions of the heart, amnion, and intestine are early manifestations of reflex motions. These appear chiefly in the involuntary muscles before connections are formed, the protoplasm of the muscle cells probably responding directly to the chemical stimulus of certain salts in body fluids, as Loeb has shown in other cases. Reflexes which appear later are the "random movements" of the voluntary muscles of limbs and body which are called forth by nerve impulse. Tropisms are manifested only by organisms capable of considerable free movement and hence are absent in the foetus . . . .[1]

The tropic mind of the germ-cell and of the fertilized ovum becomes the tropic and reflex mind of the foetus, which becomes the reflex mind of the newly born infant. Gradually, the reflex mind of the infant shows also the qualities of the instinct mind. Recent psychology describes this mind as the "unconscious mind." The first experiences of the infant are made up of contacts entirely new. A constant surrounding temperature is displaced by a variable temperature often considerably lower than that of the womb. The infant responds to these and other stimuli by crying. It does not have to learn how to cry. Hunger is a new experience. Nursing has never before been attempted. But the infant sucks for its food without being taught. These things that are done right the first time they are tried are instinctive things. The instincts are apparently adaptive and seem to be concerned with the preservation of the species.

As the days and weeks pass by the infant encounters an increasing variety of external and internal environmental experiences that stimulate its receptor organs into activity. The automatic and the reflex nervous machinery is brought more and more into use. A variety of instincts are disclosed. Emotions are uncovered and expressed. Habits are established. The infant grows in all its tissues and organs. This growth is a product of functional activity. The growth of the brain and the development of the mind are products of the functional activities of afferent, association, and efferent neurones stimulated by the experiences of the infant and child with its environment.

As the child grows older, he acquires habits. These habits involve complex nerve reflexes and higher nerve areas in the brain.

[1] Edwin Grant Conklin, *Heredity and Environment* (Princeton University Press, 1923), p. 42. See also edition of 1929, pp. 32 ff.

Under the influence of repeated experiences in the life of the child, memory develops. We believe that memory in this sense is a product of the development of synapses in the cerebral cortex and higher nerve centers. With added experience the child finds many unsatisfactory impressions. He tries many things, some of which please. He goes through "a process of many trials and errors and a few trials and successes." His habits, his memory, his trials and errors and successes give him bases for comparisons and for the formation of judgments. Intelligence and reason may thus be gradually acquired. The "conscious mind" is developed.

With an increasing diversity of contact in a physical and social environment, the growing child learns by experience to inhibit certain unattractive or undesirable afferent sensations (feelings and emotions) and discard them in favor of others to which it chooses to give attention. Along with this inhibition comes selective choice and then a consequent behavior or freedom of action which is a product of what we call "will" or "conscious choice."

Under the influence of memory, intelligence, reason, and will, all of which are products of external stimuli brought to bear upon the nervous system, the maturing mind exhibits the phenomena of consciousness.

> The most complex of all psychic phenomena, indeed, the one which includes many if not all the others, is consciousness. Like every other psychic process this has undergone development in each of us; we not only come out of a state of unconsciousness, but through several years we were gradually acquiring consciousness by a process of development. Whether consciousness is the sum of all the psychic faculties, or is a new product dependent upon the interaction of other faculties, it must pass through many stages in the course of its development, stages which would commonly be counted as unconscious or subconscious states, and complete consciousness must depend upon the complete development and activity of the other faculties, particularly associative memory and intelligence.[1]

During the several years in which the child mind is developing into the adult mind, the stimulations from environmental experience are continually transmitted into feelings and emotions, the qualities and influences of which depend upon such other psychic factors as intelligence, reason, and will.

[1] Conklin, *op. cit.*, edition of 1923, p. 53.

The mind of the newly born child is a mind of possibilities. It has a heritage of tropisms and reflexes, a heritage of native tendencies or instincts, a heritage of native intelligence and of capacities to learn. The real mind, the conscious mind, the adult mind, is the product of a gradual development of psychic faculties, potential in the infant mind, under the stimulation of nerve impulses brought into the brain from its environment during infancy, childhood, and youth.

Relation of child play to mind.—During the period of childhood, the great process of bringing in nerve stimuli to the brain and cord may be largely covered and described by the word "play." The most constant, the most quantitative, the most diversified, and the most qualitative exercises of all levels of mind are composited in the normal, vigorous play of childhood. Play is an instinctive activity. The normal child does not have to learn to play.

The exercise of infant mind and of the child mind compels the development of adult mind. Every one of the thirteen thousand million undeveloped neurones with which it is said the nerve system is equipped at birth must be stimulated and used before its functions will become relatively perfect parts of the machinery and operations of the body as a whole. This usage develops mind. In fact, it compels the development of mind. An unused neurone under the law of exercise atrophies. If never used, it never really lives. A neurone that is used is stimulated by that use to build up its own structure—its cell body, dendrites, axon, collaterals, and terminal arborization—out of food material brought by the blood and lymph. It is stimulated thereby to repair its own damaged structure, restore its structural losses, and manufacture whatever materials it may need for the generation and conduct of its own nerve impulses in response to stimuli or for the establishment of closer synapses with other neurones. A used neurone, an exercised neurone, contributes to the development of mind.

The first years in the lives of all animals that pass through a period of infancy and childhood, and particularly human animals, are devoted to this constructive program of mental development. Under the influence of functional stimulation the human brain gains in weight for eighteen years—the first eighteen years in the life of the individual. This is the period in which the exercise of human neurones may be most productive in construction and function

values. *The most powerful influences upon the developing mind and social personality in these years come from the play life of the child.*

The varied, lively, enthusiastic search for pleasing sensations and for satisfying feelings that characterizes the play of childhood brings into service in the play life of children every selective detector of stimuli present in human receptor organs. The infant with a wonderful and complicated but unused receiving apparatus becomes a child and then a youth with a receiving equipment that has been improved or even perfected by use.

The play life of the child is filled, not only with discoveries of pleasing and displeasing sensations and emotions, but also with all sorts of motor reactions to such afferent stimuli. The efferent nerve system responds inevitably to the gradually increasing variety and intensity of sensory stimuli that come with the transitions from infancy to childhood and to youth. The games and plays of these periods are full of action. The skeletal muscles (voluntary muscles) and the neurones that control them are stimulated into activity and trained into co-ordinated service by the thousands of sensory nerve stimuli that come in from the play life of the child and bombard the neurones of the cerebro-spinal axis.

With the reception of the first afferent nerve stimulations in the newborn infant, a path (or chain) of neurones conducts these first nerve impulses to the proper nerve center in the brain. Because of a hereditary equipment and relation the paths of these first impulses are established by synapses along lines of least resistance that lead to the right place or the right places.

The play of the infant is an instinctive drive for pleasing sensations—for satisfactions. The first responses to afferent stimuli are reflex or instinctive responses. This is the service of the reflex mind and the instinct mind. Because of a heritage of dormant instincts the first motor responses of the infant to first stimuli are logical responses. They are adaptive. They are protective. They are right. They are not products of intelligence or reason. These responses do not require training and learning even though they may be improved by usage. The life of the infant then is a life of instinctive and emotional activities that have been developed out of dormant, native tendencies. Its play is an instinct search or drive for pleasing sensations and pleasing motions that give

satisfaction. Out of its play the child builds a life of instincts, emotions, and emotional expression.

The instincts or native tendencies of the infant lead to the formation of *habits*. Repeated, co-ordinated experiences of afferent neurones, association neurones, and efferent neurones establish habits. The older infant, the active child, and the active youth are in the greatest and most favorable period for habit formation. The games and play of this period contain the most numerous and the most impressive and stimulating opportunities that life has to offer for habit-formation and habit-training. It is here that instincts and emotions may be most easily and effectively guided and controlled. It is here that *character* is made. The play of childhood fashions the *personality* of maturity.

Out of the play of instincts and the play of habits in this period come the higher qualities of mind. The game-life of the child is built on the basic functions of nerve, muscle, and other tissue cells. Because of these, the play of children is made out of feelings of pleasure and pain and of consequent emotions and emotional expressions and experiences. Because of these the play life of children is a leading out or uncovering of native instincts. With these fundamental drives the play life of the child gradually develops the mind of the child and the mind of the adult. If the forces of constructive mental hygiene are present in the play life of the child, the adult mind that is being fashioned thereby will be a healthy mind.

> We may say .... directly or indirectly the instincts are the prime movers of all human activity; by the impulsive force of some instinct (or some habit derived from an instinct), every thought, however cold and passionless it may seem, is borne along toward its end and every bodily activity is initiated or sustained .... Take away these instinctive dispositions with their powerful impulses, the organism would become incapable of activity of any kind; it would lie inert and motionless like a wonderful clockwork whose mainspring had been removed or a steam engine whose fires had been drawn.[1]

The play urge is common to all normal children and to the young of many animals. The play of childhood and youth makes use of an infinite variety of activities and situations. Imitation and imagination come early and add a rich supply of varied ex-

[1] William McDougall, *An Introduction to Social Psychology* (John W. Luce & Co., 1921), p. 45.

periences to the life of the child. The busy, natural play life of the child brings a use and exercise of sensations and a formation of reactions. In the language of the psychologist, there is a consequent development of ideas, percepts, mental images, imagination, memory, feelings of relationship, feelings of meaning, judgments, emotions, impulses, desires and wishes, deliberations, decisions and choice, power and will, interest with self-expression, attention with self-control, that constitute mind and qualify and modify character and personality.

The satisfaction of the play-hunger of the normal child must be a source of satisfaction to the child. The experiences that bring dissatisfaction are avoided. They do not belong to play. The desirable and wholesome play life of the child must then be a life of happiness and joy—a life of wholesome, desirable emotions.

A childhood play experience that is rich in wholesome, pleasing sensations and rich in wholesome, happy, mental responses is an experience that makes for wholesome mental hygiene. It is an experience that stores the mind with memories which safeguard sanity. Habits of joyous play tend to build sound mental health.

Constructive values of adult play.—But play as a factor in constructive hygiene is not limited to childhood and youth. Its constructive values in relation to mental health are greatest in these earlier age periods, but they are present in all age periods. The play of children is characterized by an accompanying, interwoven, essential, vigorous physical exercise. The play of youth is associated with sports and competitive athletics as well as with social pleasures and entertainment. The play of advancing years is less and less vigorous. The element of physical activity may unfortunately disappear, but the search for satisfaction is still present. We then use the terms recreation, entertainment, amusement. The protective, and conservative, mental-hygiene values of play persist whether the activity be described as recreation or entertainment or as interesting work, active or passive, provided it is wholesome. Mental health is not a product of vicious play, nor is mental health conserved by vicious leisure.

Play is an essential factor in the constructive mental hygiene of the child; and the mental hygiene of the child is the determining factor in the mental hygiene of the adult that is to be.

"We make most out of nature's gifts by (1) encouraging the useful instincts and capacities, (2) inhibiting harmful ones, and

(3) by so arranging life's work as to have natural tendencies assist rather than oppose it."[1]

In childhood and youth the most important life work is play. Play in any age period to be wholesome and to be protected from vicious influences must be safeguarded and defended. Psychiatry, that branch of medical science that deals with mental disease, is concerned very largely with unhealthy adult minds in sanitariums, hospitals, and asylums, representing the end penalties of unguarded childhood play.

The responsibility of the adult for the play life, and therefore for the mental hygiene of the child, must be pointed out.

> . . . . what we are at any time depends upon what we have been and done in the past; but . . . . we are almost sure to make two errors—to suppose (1) that much in our lives is due to chance and (2) that by an act of will we can at any time blot out the past and begin again . . . . every thought and act in life counts . . . . we build the ladder by which we climb . . . . nothing happens by chance . . . . a few indulgences in some useless or bad habit are of small consequence but they are of some consequence, nothing of good or use is ever lost; we may forget and forgive, *but the neurones never forget or forgive.*[2]

Since every event of mental life is written indelibly in the brain's archives to be counted for or against—not at some far-off judgment day but at every future step in the mental career[3]—it follows that the parent, the guardian, and the citizen have a serious obligation in relation to the events of mental life that are "written in the brain archives" of childhood, youth, and other dependents.

Ideally, every moment in the life of the infant, child, and developing youth should be accounted for unobtrusively by a helping, directing, safeguarding, unirritating adult supervision. The earliest program of supervision involves an adult responsibility for the nutrition, excretion, and sleep of the infant. There is always a responsibility for health examination, repair, and treatment. To this program there is very soon added the responsibility for play. The happy baby, the baby that laughs and crows, is beginning its play life. There is an adult responsibility involved in

[1] Edward L. Thorndike, *Elements of Psychology* (A. G. Seiler, 1922), p. 151.

[2] *Ibid.*, p. 330

[3] Quoted with slight change from Thorndike, *Elements of Psychology*, A. G. Seiler, 1922, p. 331.

this new item that brings an obligation to furnish conditions and opportunities that will make this play normal, satisfying, and wholesome, without in any way disturbing nutrition, excretion, or sleep by overemphasis. The "entertainment" of a few-months-old baby may be easily overdone.

The program of later infancy and childhood includes all these elements with a greater emphasis upon the habits of play. The "events written indelibly in the archives of the brain" multiply in variety and repetition. Joy, happiness, cheerfulness, and pleasing temperament are objectives to be achieved by intelligent, alert but unobtrusive, mature supervision. In another text the damaging effects of fear and terror, of rage and tantrums, of jealousy, of sexual emphases will be discussed. Constructive hygiene requires that such damaging influences as these shall not be permitted to enter into the life of the child.

The play of childhood and youth brings on a growing complexity of experiences that lay the foundations of character and determine the mental and social behavior of a lifetime. The beginnings of "work" and the expansions of play activities in a period characterized by imagination and imitation and later by the "gang-spirit" place a responsibility upon parents, older brothers and sisters, and the adult community environment that is more often neglected than met. A constant though unobtrusive adult influence may be exercised in the direction of fair play, recognition of the rights of others, honesty, honor, sociability, good nature, self-reliance, self-control, obedience, and other important elements of good character and social conduct. These are influences in the adult environment that are essential to the wholesome play life and therefore to the satisfactory mental hygiene of the child and the youth, and, through those periods, to the social and mental hygiene of the adult. The responsibility of the adult in the home, the school, and the community, for the play life of the child is therefore in addition a significant responsibility for the mental hygiene of the man or woman that the child is to be.

CHAPTER XVII

REST: AN ESSENTIAL PRINCIPLE OF CONSTRUCTIVE HYGIENE—PRIMARILY A PRINCIPLE OF CONSTRUCTIVE SOMATIC HYGIENE

One may secure rest of varying degrees of completeness in various ways. One rests himself by reducing or moderating the pressure of his mental, physical, or social activities. Rest may be achieved by such expedients as changing from one activity to some other activity, substituting a more satisfying activity for a less satisfying one, doing an interesting something in place of a monotonous nothing, changing to a new or more attractive environment, stopping tiresome eye-work or other irksome or painful sensory activity, relieving one set of muscles by using another set, changing from one sort of mental activity to another more satisfying mental activity, displacing anxiety, worry, excitement, or depression by tranquillity, calmness, and peace of mind, or in other ways varying, reducing, or stopping a special active service of receptor organs, motor organs, or the association organs. A reduction or cessation of activity is most commonly and easily secured by sitting down or by lying down or by doing something interesting. The most nearly complete rest arrives with sleep. Sleep is a provision and a requirement imposed by nature in order to satisfy the biological necessity for rest. All the higher forms of animal life must sleep. Animals deprived of sleep die. All forms of life, plant and animal, probably have states or periods of rest more or less analogous to sleep.

Rest-requiring nature of tissue cell.—A review of certain facts, presented in the preceding chapters on nutrition, excretion, exercise, and play brings out the relations of cause and effect that establish the importance of rest. The causes that make rest a necessity and the effects that prove the fulfillments of certain constructive requirements satisfied only by rest are found, in large part at least, in the physiology of nutrition, excretion, exercise, and play. These important sequences of cause and effect may be briefly re-stated as follows:

1. The living tissue cell is surrounded by a fluid stream of lymph and blood from which it absorbs continuously the chemical compounds it must have if it is to remain alive and perform its

functions and be a healthy cell. From this surrounding medium the cell absorbs by osmosis and diffusion its essential chemical elements, carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur, chlorine, sodium, potassium, calcium, magnesium, iodine, and iron. These chemicals are present in the lymph and blood surrounding the cell: water, inorganic salts, blood-sugar (dextrose or glucose), amino-acids, fats, oxygen, vitamins, hormones, and other chemical compounds, known and unknown. The lymph surrounding the living tissue cell brings to it also the internal excretions of other cells in case those excretions have not been effectively removed from the blood circulation. And, in general, the living tissue cell is receiving efferent nerve impulses from and sending afferent impulses to the central nervous system.

2. The living tissue cell is continuously building, repairing, or replacing its living structure, using for the purpose certain of the chemical compounds, notably the amino-acids, that it has absorbed from the surrounding lymph. These building activities construct and maintain the living cytoplasm and nucleoplasm of the cell.

3. The living tissue cell is continuously manufacturing its own special products. These products are built up (synthesized) out of certain of the chemical compounds that the cell has absorbed from the surrounding lymph. These special products are usually called secretions. They may be external secretions or internal secretions. Among them are the digestive enzymes and hormones, insulin, epinephrin, and glycogen. The muscle-cells manufacture, among other things, a something with which they are able to produce muscle contraction. The nerve-cells manufacture, among other things, a something with which they may produce nerve impulses and the feelings, ideas, memories, thoughts, impulses and so on that we call mind. Certain gland-cells manufacture milk. The ductless glands, called the endocrine glands, such as the thyroid, thymus, and pituitary, manufacture internal secretions of very great importance to health and life, concerning which not a great deal is now known. Other cells manufacture bone. Others manufacture blood corpuscles. The cells of the testis manufacture sperm-cells. Those of the ovary manufacture egg-cells. The manufacture of special products is obviously a very important activity of the tissue cells. Numerous other examples of these special manufactures could be given. Every cell manu-

factures a special something with which it is enabled to perform its special function.

4. The living tissue cell is continuously developing its own operating power whether that power is the operation of a synapse or a germ-cell. It is in some mysterious, microscopic way, providing the osmotic and other physical energies and the chemical energies which furnish the power of absorption, of chemical synthesis, and of chemical dissociation essential to the living activities of the cell. The cell develops its own power for absorption, for construction, for manufacture, and for removal of its products.

5. Certain tissue cells, probably all tissue cells, but notably the muscle fibers, are continuously transforming potential energy into kinetic energy or heat. These processes are the thermodynamics of the living tissue cell. They are dissociations or decompositions of carbohydrate compounds that have been secured or manufactured by the cell, chiefly at least, out of the glucose brought by the blood and lymph. The decomposition of carbohydrate compounds by the cell with the release of kinetic energy or the liberation of heat is accompanied by the formation of acid wastes, notably lactic acid and carbon dioxide, and also by the formation of water.

6. Certain of the living tissue cells, possibly all of them, are continuously discharging special manufactured products, their secretions, into the surrounding lymph for transportation and storage for future use or for immediate use by other cells. This removing activity of the cell is essentially that of osmosis and diffusion. Certain living tissue cells discharge their manufactured products in other ways. The bone-marrow discharges red-blood cells into the blood circulation. The germ-plasm discharges its germ-cells into reproductive channels. The nerve-cell discharges its impulse or other mental elements into a synapse or some other end-organ.

7. These continuous activities of the living tissue cell are accompanied by a certain amount of destructive structural wear and tear of the cell. This wear and tear is a breaking down of the living chemical substance that constitutes the cytoplasm and nucleoplasm of the cell, with the consequent formation of the internal excretions, ammonia, nucleic acid, creatin, creatinin, etc., that were discussed in our chapter on excretion.

8. The living tissue cell is continuously removing the waste and refuse products that arise from its various building, manufacturing, and energy-transforming operations and from its own wear and tear. These removals are chiefly the internal excretions described earlier as containing cell irritants and poisons.

9. The living tissue cell is continually giving out heat. This heat dissipation arises from the development of operating power discussed under paragraph 4 above or from the energy transformations discussed under paragraph 5.

Chemically these sequences of cause and effect in the physiology of the tissue cell may be classified as processes of absorption by osmosis and diffusion, building up by chemical synthesis, breaking down by chemical dissociation, and removal by osmosis and diffusion.

In the language of the manager of a manufacturing plant, these activities of the cell might be described as the acquisition of operating supplies and raw materials, plant construction and equipment, power production, plant production, output, depreciation, repair, and replacement, and removal of refuse and waste.

For an easy understanding of the causes of the rest requirement and of the effects of rest of the tissue cell, the significance of these nine basic activities of the living tissue cell may be considered as processes of (*a*) absorption, (*b*) building up, and (*c*) breaking down. The building-up process is called anabolism, the breaking-down, katabolism, and the whole process, metabolism.

We have stated that, "Rest is a reduction or cessation of activity." But these activities of the tissue cell never cease. They may increase in their intensities or rates. They may decrease. They do not stop while the cell is alive. Cell rest is a reduction in cell activity; but, curiously, cell rest does not consist in a reduction of the building-up processes. Cell rest is a result of a decrease in the breaking-down processes in the cell with no corresponding decrease in the building-up processes. It is a lessening of destructive activity but not a lessening of constructive activity.

Tissue-cell rest.—1. A necessity for cell rest develops when the breaking-down process of the cell uses up the materials manufactured by the cell or available to the cell for functional services faster than those materials are supplied. If the demand is great and urgent and the decomposition rapid and prolonged, the re-

quirement for rest will be acute. If the rate of the breaking-down process is in only moderate excess of the rate of manufacture, the immediate rest requirement will be correspondingly mild and the urgent need proportionately delayed. Such occasions for cell rest are most obvious in relation to the functional activities of muscle-cells, nerve-cells, and gland-cells.

2. A need of cell rest arises in case the breaking-down processes were so excessive as to produce internal excretions more rapidly than they could be removed from the cell or from the lymph and blood surrounding the cell. This requirement for rest is most likely to arise as a result of the functional activity of voluntary muscle-cells.

3. An occasion for cell rest arises in case the internal excretions produced by the breaking-down processes of the cell contain toxic compounds that are neutralized or eliminated from the blood more slowly than they are produced by the cell. Under these circumstances these injurious internal excretions would accumulate in the blood and affect all the cells of the body. We have very convincing experimental evidence of the presence in the blood of such toxic products.

4. A need for cell rest appears in case the products of the activity of the cell cause increasing feelings of reluctance to continue the activity or of resistance, repugnance, or intolerance toward carrying on the activity, or feelings of depression, worry, or excitement that may not be apparently related to the activity.

A feeling of dissatisfaction or of depression, worry, or excitement is a product of a mental function. The unsatisfactory feeling is thought to be the effect of a stimulation of certain cortical synapses directly by chemicals in solution floating in the blood and lymph and brought therein to those synapses from active cells somewhere else, near or far. Or the feeling may be the effect of the neurone's own katabolic products stimulating those of its own synapses that are concerned with making these unpleasant feelings. Or the feeling may be the effect of nerve impulses reaching these synapses from some receptor organ that has been stimulated by some mechanical, physical, or chemical agency associated with the functional activity of some organ. These theories of the anatomy and physiology responsible for the unsatisfactory feelings that may accompany cell activity are not supported by final proof.

We cannot now go farther than to state that these relations of cause and effect between the synapses of the cerebral cortex and the products of cell function are well within the range of possibility and probability.

5. A further occasion for cell rest appears in case the conditions under which the cell activity is carried out or the mechanical, physical, or chemical effects of the cell activity cause pain, distress, or discomfort. If such influences are multiplied by the activities of many cells, the demands for rest become imperative.

Effects of cell rest.—1. Cell rest involves a reduction in the rate of the breaking-down processes of the cell, and enables the cell, through its building-up processes, to replace functional material more rapidly than it is used. Under these circumstances, cell rest would restore losses and promote the storage of reserve products. There would be a gain in cell weight.

2. Cell rest that involves a reduction in the functional activity of the cell may cause a reduction in the structural wear and tear of the living protoplasm of the cell and thus give, in consequence, a better opportunity for restoration through structural repairs and replacements, and, in the earlier age periods, for gain in the structural growth of the cell.

3. Cell rest that reduces the breaking-down processes of the cell will also reduce the amount of refuse and waste material to be excreted from the cell. This reduction in the amount of the internal excretion of the cell gives opportunity for the more complete removal of such excretions from the lymph and blood around the cell and for the neutralization of those excretions and their final elimination by the organs of external excretion. Cell rest therefore protects the tissue cells from injury from an accumulation of toxic circulating internal excretions.

4. Appropriate cell rest may remove the causes or neutralize the effects of those products of cell activity described above that stimulate certain cortical synapses to produce feelings of opposition to the continuation of the activity, or of dissatisfaction with the activity. Or cell rest may remove the causes or neutralize the effect of those products of cell activity that reach these cortical synapses, directly or indirectly, and cause cumulative and persistent feelings of depression, fear, worry, or excitement.

5. The rest of cells or of organs whose activities are causing discomfort or pain to themselves or to other cells relieves such

distress and promotes nervous and mental comfort. Such relief may have a very definite constructive health value; for instance, the rest and relief of eye-strain may remove the cause of an unpleasant or even incapacitating headache.

Sources of the individual's need of rest.—The causes that make rest a requisite to the health and life of the tissue cell are summated by an infinite number of tissue cells into the causes that make rest a requisite to the health and life of the individual of whom those cells are a living part.

The daily life of the individual with all its regularities and with all its irregularities and its emergency experiences is a composite product of the services contributed by an immense number of living cells, combined into the various tissues that form the organs of which the individual is made. The demands for rest that arise in the daily life of the individual are not demands from individual tissue cells, nor from individual organs. We may speak of a "tired heart," or of "weary muscles," or of a "fatigued mind"; but a scientific analysis of the need for rest proves that it concerns more than the local organs named. The body works as a whole. Its experiences are not those of individual organs. Its fatigue is always a combination of the needs for rest that have arisen in all the organ-systems of the body. The skeletal muscles, the bones and joints, the heart and circulation, the respiratory organs, the skin, the endocrine glands, and the nervous system are most prominently represented as contributors to our needs for rest. Fatigue is more or less a fatigue of them all.

Our analysis of the causes of the need for rest in the tissue cell has disclosed five causes. The necessity for rest in the life of the individual is not due to any single one of these causes. One is tired, wearied, fatigued as a result of all these causes working together. One or another cause may predominate under one circumstance or another, but it is important to regard all these causes as one composite cause, even though our analysis here must take them up one at a time.

The need for rest on the part of an individual is always partly mental. The feelings of fatigue, the desire for rest, are mental evidences of bodily needs. The causes of fatigue, wherever they are, can be made known only through the medium of the mind. One thinks of rest, or longs for rest, if the activity in which he is engaged is uninteresting, monotonous, or unpleasant.

The wish for rest becomes more insistent if the activity brings discomfort or pain, discontent, repugnance, or intolerance.

A consciousness of rapid, difficult, labored breathing, of aching, straining muscles, of blistered hands and bruised fingers, of sore feet, establishes and supports a desire for rest. Headache, dry heavy eyes, sleepiness, are usually symptoms of a need for rest. Persistent discontent, dissatisfaction, or worry may be mental evidence of a need for rest which if neglected may lead to very real mental injury.

These feelings that give evidence of the need for rest are mental records of events that have taken place or events that are taking place in the lives of the tissue cells of the whole body, the brain included. They take place as described above in our discussion of tissue-cell rest. In the language of a preceding chapter we may state that the receptor neurones unite the association neurones with all the organs of the body.

A microscopic examination of the cortical brain cells and of the spinal motor cells of certain animals shows that fatigue is accompanied by evidences of change in those cells. Under the extreme influences of experimental fatigue the neurone bodies in the cerebral cortex of dogs are found distorted and shrunken and changed in their chemical reaction (Pieron). The fatigue of the day's activities has been shown to produce a similar effect upon the spinal motor nerve-cells of sparrows (Hodge). Obviously there has been in these neurones an excess of breaking-down. The anabolic processes have not balanced the katabolic expenditures. We have here microscopic proof that the need for rest after voluntary muscular activity appears not only in the cells of the muscles involved but also in the neurones of the spinal cord and of the cerebral cortex.

The individual requires rest when his expenditure of energy has exceeded his income of energy. This is another way of stating that one requires rest after the chemical breaking-down processes in his tissue cells have overbalanced their chemical building-up processes. We require rest when our katabolism exceeds our anabolism. During rest we reduce our losses from katabolism and accumulate potential energy through anabolism. In a preceding paragraph on basal metabolism we noted that a man doing severe muscular work may "burn up" enough fuel foods in his tissue cells to produce 653 calories of heat per hour. This means

that his katabolic processes break down the carbon compounds that his tissue cells have built up and are building up at such a rapid rate as to produce 653 calories of heat per hour during the severe muscular exercise. We noted further that when this man stopped work and simply stood still, his rate of heat production was reduced to 114 calories per hour. Sitting down in a chair reduces the production of heat still more. Lying down and going to sleep reduces the production of heat to a rate of 65 calories an hour. The rate of heat production during sleep is one-tenth the rate of production during severe muscular work.

The individual requires rest when his internal excretions are produced more rapidly than they are removed. In our chapter on physical exercise it was noted that the carbon dioxide output from the lungs might be increased by vigorous exercise to a rate twelve times that of the resting average. Under the influence of such a severe muscular activity, the output of blood from the heart to the lungs for the elimination of carbon dioxide and for the dissipation of heat by the lungs may be increased ten- or twelvefold.

Respiratory difficulty is a common experience during vigorous muscular exercise. This difficulty is caused by the burden of physiological work thrown by general muscular activity on the heart and the lungs and their consequent obligation to prevent a progressive accumulation, in the blood, of heat and of carbon dioxide and its antecedent internal excretions. The effects of rest upon such activity are to restore the balance between carbon dioxide production in the tissues and its excretion by the lungs and its utilization by the liver.

The individual requires rest when his heat production exceeds the capacity of his cooling processes. The greatest production of heat accompanies voluntary muscular contraction. But every active cell produces heat. Cell heat is transmitted to the lymph and blood that surrounds the cell. The blood is cooled by the respiratory evaporation and ventilation in the lungs and by the evaporation of the perspiratory secretions of the skin.

The individual requires rest, in part perhaps because of a sleep-producing toxine that accumulates during activity. One needs rest when certain internal excretions accumulate in the blood in such amount as to produce mental evidence of fatigue. The feelings of weariness and drowsiness that come at the end of the day or after unusually tiresome activity are probably due in part to the

presence in the blood of certain internal excretions which have been called fatigue products. Experimentally the transfusion of blood from a tired dog into the circulation of a rested dog produces symptoms of fatigue in the rested dog. These internal excretions are called toxines. Physiologists who have experimented with fatigue and rest describe a "hypnotoxine" which has been found in the blood and in the fluid of the spinal canal and of the ventricles of the brain of fatigued animals. Hypnotoxine is an internal excretion. It is a product of the breaking-down processes (katabolism) of certain, possibly all, living tissue cells. Its accumulation in the blood and in these other fluids produces drowsiness in rested animals after the transfusion or injection of such blood or other fluid into the blood circulation or into the spinal cord or the fourth ventricle of the normal animal.

Other causes of the necessity for rest are described in the various explanations of the cause of the necessity for sleep. (*a*) It is stated that sleep is an effect of the influence of acid waste products originating in the fatigue of nerve and muscle. Lactic acid is a product of muscle fatigue. The injection of lactic acid into the circulation produces evidence of fatigue which may be pushed to unconsciousness. In accordance with this theory, the acid fatigue products, carried by the blood circulation, would diminish the irritability of the neurones of the cortex of the brain and thus induce sleep. (*b*) ". . . . periodicity of sleep is dependent mainly upon a rhythmical loss of tone in the vasomotor center in the medulla in consequence of fatigue from continued activity during waking hours."[1] In accordance with this theory, the neurone center that controls the blood supply to the brain becomes fatigued during waking hours. The fatigue of this controlling nerve center leads to a decrease of the blood supply of the brain. Because of this anemia, the neurones of the brain become less irritable, and drowsiness and sleep are produced.

Effects of rest upon the individual.—The effects of rest described for the tissue cell are multiplied and composited for the individual by all the infinite, unnumbered total of tissue cells that constitute the individual. These effects may be stated as follows:

Rest causes a reduction of katabolism. The individual at rest

[1] W. H. Howell, *Text-Book of Physiology*, tenth edition, 1927, W. B. Saunders Co., p. 269.

reduces or stops the katabolisms that produce voluntary activity. Indirectly he reduces also the katabolisms of some of his involuntary organs, that is, the organs under the control of the autonomic nervous system and not directly under the control of the will. These organs were discussed to some extent in our chapters on exercise and play. They include: the heart, arteries, and veins; the more important respiratory muscles; the digestive organs; the endocrine glands; the reproductive organs; the kidneys; and certain other organs. Under the influence of rest certain of these involuntary organs reduce their dissimilatory (katabolic) changes. For example, the heart beats more slowly and less vigorously and the respiration is slower.

This reduction of katabolism consequent on rest is chiefly, some investigators maintain wholly, a reduction in the decomposition of the energy- and heat-producing carbon compounds. The katabolism of the protein structure of the cell, its cytoplasm and nucleoplasm, is thought by some observers not to be affected by rest. Others have noted a reduction during rest.

Rest causes a positive or relative increase in anabolism. Structural growth continues during rest. Repair and replacement of structural losses goes on. The manufacture of potential-energy containing compounds and of other special functional compounds continues.

After adequate rest, the cortical neurones are no longer distorted and shrunken nor of acid reaction in the brains of the dogs that had been fatigued, as described above. The motor nerve-cells in the spinal ganglia of the sparrows to which reference has been made are normal in the morning. Their shrunken cytoplasm and nuclei are restored from the conditions of obvious fatigue as shown under the microscope in the evening after an active day's fatigue. The effects of rest upon these nerve-cells may be regarded as typical of the effects of rest upon all the tissue cells. The football player who has lost ten pounds in a hard game will very soon restore his loss under the influence of his food supply and rest.

Rest causes the rate of the removal of internal excretions, including acid wastes and fatigue toxines and heat, to exceed and then to equal the rate of their formation. Rest decreases the production of heat and the amounts produced of some if not all the internal excretions, but it does not interfere with the removal of those products. During sleep the amount of carbon dioxide ex-

creted from the lungs may be reduced to one-tenth the amount excreted during severe exercise, but it does continue. After adequate rest, the hypnotoxine described above is no longer found in the blood.

Rest removes the uncomfortable, painful, dissatisfying, or intolerable products of activity. These effects of rest are covered in part in the preceding paragraph. The products in question may arise because of irritating internal excretions (i.e., acid and toxic fatigue products) or because of mechanical pressures or injuries or they may be of mental origin. Rest removes the weariness and tiredness that result from an accumulation of internal excretions; it restores comfort to a sore and aching muscle; and it removes the headache of mental fatigue or the intolerance of mental dissatisfaction with the activity in hand.

Rest promotes growth. The effects of rest upon katabolism, upon the physical and mental products of fatigue, and upon anabolism combine to make rest an important constructive influence upon growth.

The prenatal period is a period of nutrition and rest. It is the period of most rapid growth and of greatest growth in the life of the individual. Katabolism is at a minimum; structural anabolism is at a maximum; rest is continuous.

The periods of infancy and childhood are growth periods in which rest is of very great importance to the full realization of inherited growth possibilities. Sleep in large quantities is essential to the normal growth of the infant and child.

Growth in the length of the long bones continues in girls until they are about fourteen years of age and in boys until they are eighteen. The growth of other organs, notably the brain, continues in both sexes ordinarily during the first eighteen years of life. These earlier years are the years in which rest, particularly sleep, is most essential. It is in these years that rest contributes its greatest constructive influence upon growth.

Rest promotes repair and replacement. There is a lack of convincing information relative to the relation of rest to the repair and replacement of the living structure of the tissue cells. It may be that the tissue cells repair their structural damages and replace their structural losses continuously or as they occur. It would seem logical, however, to suppose that the structural wear and tear is greater during the busy, functionally active, waking

hours and less during periods of reclining rest and sleep. It would seem logical, too, to suppose that the repair of the living protein structure would be greater during sleep than during vigorous bodily activity. There is some evidence that rest has such an influence upon the protein metabolism. "According to Siven there is a distinct diminution in the secretion of the endogenous purin nitrogen" during sleep.[1] In other words, Siven finds evidence that there is a decrease in protein katabolism, that is, structural wear and tear, during sleep. A relative increase and perhaps a positive increase in structural anabolism is the logical accompaniment of a decrease in structural katabolism.

Rest promotes the restoration of mental and physical energy. A great Italian physiologist, Angelo Mosso, demonstrated experimentally the restorative effects of rest. Mosso and his pupil, Maggiora, investigated fatigue and rest. Among other things they noted that, using a heavy weight and a rapid rate of contraction, the voluntary muscles soon tire and are unable to continue lifting the heavy weight at the rapid rate. But they found that by adjusting the weight to be lifted and the interval of rest between liftings a weight and a rate could be found with which the muscles could contract indefinitely. If the energy expended in lifting the weight each time was not too great, an interval of rest could be found that would be long enough to restore the energy used each time in lifting, so that the work could go on indefinitely.

Rest promotes the restoration of mental energy as well as the energy with which one does mechanical work. It is necessary only to refer to the common experience of us all with the influence of sleep upon our mental and physical energy to make this fact clear.

Rest favors a maintenance or increase in weight. The loss of weight due to katabolism is least during sleep. An accumulating storage of reserve materials in the tissues may follow an ample food supply and a good deal of rest. Under ordinary circumstances the maintenance of weight is rather directly related to rest. Other influences remaining the same, there will be an increase in weight with an increase of time spent in sleep or other form of rest involving a decrease in katabolism.

Rest favors the restoration or improvement of function. The restoration or improvement of function after rest is illustrated by

[1] W. H. Howell, *op. cit.*

the influence of rest upon the contractile function of the voluntary muscles. A group of motor nerves and muscles fatigued to relative exhaustion will be restored to functional ability after a period of rest and nutrition. The functional services of the glands of the body if reduced because of activity will be restored after rest. The evidences of the functional depletions of fatigue and the restorations of rest in glandular organs may be demonstrated under the microscope. Microscopic evidence cited in previous pages relative to the influence of rest on the content of motor neurones may be cited here as evidence of the restoration through rest of the materials with which the neurone produces and transmits the nerve impulse. There is convincing evidence of fatigue and of restoration through rest, of the functions of the receptor organs discussed in a previous chapter. It is probably true that rest restores to the fatigued neurones of the cerebral cortex the materials with which they produce their special mental activities. One of the most important and, at present, least understood constructive relations of rest exists between rest of various types and the consequent restoration of the functions of mind.

The rest of a mental functional activity removes the products of that activity that resist, inhibit, or block the continuation of the activity. These mental work-resisting products are felt by the individual as indifference, inattention, sleepiness, dissatisfaction, distraction, effort, discontent, impatience, irritation, depression, repugnance, intolerance, revolt, and similar activity-opposing feelings. These mental obstacles to the continuation of a mental activity or to an activity that is chiefly mental[1] or even chiefly physical, influence the individual to remove the unpleasant feeling by reducing his activity or by discontinuing it or by adding to the activity an interest, motive, or purpose, the mental products of which will neutralize or displace the dissatisfying, activity-blocking, mental products.

The "rest" of a frequently recurring or persistent emotion removes the damaging products of that emotion. These products are exhibited in the individual mentally as dominating moods, of anger, rage, jealousy, fear, anxiety, worry, or regret, with exhibitions of depression, apathy, or excitement. The bodily effects of

[1] The need for the rest of a mental activity is often confused with the need for the rest of organs that are working in requisite association with that activity. For instance, eye-fatigue is often interpreted as mental fatigue.

such emotions are evident in disturbances of digestion, circulation, blood pressure, and respiration.

Preventive or curative rest of such emotional disturbances may sometimes be achieved through the removal of physical fatigue and mental fatigue, and by adding or substituting mental activities whose products are mentally satisfying.

A mental rest from activities that produce persistent worry or excitement by the substitution of activities that produce mental peace, tranquillity, and equanimity, wholesome joy, happiness, and satisfaction is a mental rest that conserves and constructs mental health.

Control of rest.—Our control of rest is secured through sleep and through our control over the voluntary motor functions, the voluntary sensory functions, and the voluntary mental functions of the body. Our control over these voluntary motor, sensory, and associative functions gives us an indirect control over the involuntary functions of the body.

Sleep.—"The central and most important fact of sleep is the partial or complete loss of consciousness, and this phenomenon may be referred to a lessened metabolic activity in the brain tissue, presumably in the cortex cerebri . . . . the entire cortex does not fall asleep at the same instant nor always to the same extent . . . . ordinarily as sleep sets in the power to make conscious movements is lost first and the auditory sensibility last, and on awakening the reverse relation holds. The individual may be conscious of sound sensations before he is sufficiently awake to make voluntary movements."[1]

Sleep suspends all voluntary activities and reduces some, possibly all, of the various activities produced by the different involuntary katabolisms of the body. Sleep brings the most nearly complete rest of body and conscious mind possible. While sleep is to some extent under voluntary control, it is ultimately a requirement imposed by biology that cannot be escaped by the normal individual. Sleep may therefore be regarded as involuntary rest, in contradistinction to the various forms of waking rest that are largely voluntary.

The controllable conditions that encourage sleep have been listed and described by Hough and Sedgwick as:

[1] W. H. Howell, *Text-Book of Physiology* (W. B. Saunders Co., eighth edition), p. 254.

. . . . (1) *moderate bodily fatigue:* . . . . moderate fatigue favors slumber; over-fatigue and especially muscle soreness or lameness often render it more difficult. Many people suffer from insomnia because of a lack of muscular activity; others because of injudicious muscular activity. (2) *Dilation of the arterioles of the skin:* . . . . it is difficult to go to sleep when the skin is cold, or indeed when only the feet are cold. When the skin is cold its blood vessels constrict and we cannot secure the needed dilation in that organ. [The reduced blood supply of the brain that plays at least a very prominent part in establishing our daily requirement for sleep is accompanied by and made more easily possible by the dilation of the blood vessels of the skin. This dilation assists in the withdrawal of blood from the brain.] Sometimes . . . . the addition of a light blanket to the bed covering brings on sleep within a few minutes [after several hours' sleeplessness without consciousness of being cold]. . . . . The use of warm drinks or a tepid bath before retiring also finds its explanation in the cutaneous dilation thereby induced. Very hot baths—by overheating the skin and stimulating the afferent nerves of warmth—often delay the onset of slumber. Too much bed covering often has the same effect. (3) *Exclusion of afferent impulses:* To secure rest to the efferent neurones and, indeed, to the central nervous system in general, they must be protected from afferent stimulation . . . . room darkened . . . . sound excluded . . . . sense organs of other senses . . . . protected from stimulation.[1]

Avoid stimulation by cold, heat, excessive muscular fatigue, or bodily discomfort from constricting bed clothing or any other cause. Secure muscular relaxation and mental tranquillity in preparation for sleep.

Voluntary rest.—The central fact of voluntary rest is the removal of the damaging or dissatisfying effects of the motor, sensory, and mental activities directly or indirectly under the control of the will. Such removal may be accomplished in the following ways:

1. Interrupt the activity (motor, sensory, or mental) with short periods of inactivity. In this manner one establishes a rate of motor, sensory, and mental work in much the same manner in which the heart carries on its work. The heart never stops work. It rests after each beat. In its regular waking routine it may "work" 72 times a minute and rest 72 times a minute. For a period of time it may work much harder and beat at a rate of 120 or 140 or even a greater number of times a minute, taking a proportionately shorter rest after the work of each beat. During

[1] Hough and Sedgwick, *The Human Mechanism* (revised edition, Ginn & Company, 1918), p. 335.

sleep this work and rest rhythm may be 60 a minute, or even lower. One may adjust his muscular work, eye work, and mental work or his combinations of motor, sensory, and mental work so that he rests as he carries on his work.

2. Add an incentive that will put interest into the work and thus neutralize or destroy the work-obstructing products of the previously monotonous or unpleasant activity. Weariness and fatigue disappear on the arrival of an absorbing interest. "Work" then becomes "play." Edward L. Thorndike has discussed ways of diminishing or removing resistance which blocks mental work. Since all human work is a varying composite of motor, sensory, and mental work, Thorndike's discussion may be applied here to our discussion of voluntary rest. He states:

> The resistance which blocks mental work may be diminished by supplying interest and motive . . . . certain kinds and amounts of mental activity are maintained without external subsidies, but much of what has to be done creates in the doing ennui, repulsion, and pain and deprives the worker of various satisfiers. The worker is thereby impelled to decrease, intermit, or abandon the work. . . . . The same work done with interest does not so soon produce ennui and repugnance. The denial of certain satisfiers, such as games, conversation, or reverie, may be balanced by new ones, such as money-reward, zeal to improve, or confidence that the work will benefit one's self or others. . . . . The limit of work for every man is elastic as the pull of interest and personal profit . . . . as a muscle becomes anew responsive to the stimulus when the toxic products of the contraction are washed out or neutralized, so a mental function may be made to continue its output by washing out the repugnance and need for effort by an interest and neutralizing the pain of restraint by a motive.[1]

3. Lessen the pressure or intensity of the work. This result may be accomplished by prolonging the rest periods as suggested in paragraph 1 above or by reducing the motor, sensory, or mental burden to be carried. One rests by making his activity easier to carry on. He lightens his work by doing less of it in a given time.

4. Discontinue the "work" (activity) and substitute inactivity or play.

5. Transfer to a new and different activity. This form of voluntary rest is in reality resting from an activity by discontinuing that activity. If the new activity is wholly different from

[1] Edward L. Thorndike, *Educational Psychology,* Vol. III (1921), pp. 126 ff.

the old one, the change will be a rest so far as the older activity is concerned. One may tie bundles all morning and rest by driving a truck all afternoon.

6. Discontinue the activity and take a "nap." Certain aspects of this voluntary rest need further discussion.

Rest of the voluntary motor system.—The skeletal muscles that form by far the greater part of the voluntary motor system represent over 40 per cent of the weight of the body. The importance and the constructive values of adequate rest for the voluntary motor system arise not only from the great mass of living tissues involved directly but also from the extent to which the organs of the other bodily systems are necessarily and profoundly influenced by consequences of the activities and rest of the voluntary motor system. We discussed the effects of physical exercise in an earlier chapter. In like manner physical rest, or rest of the voluntary motor system, affects directly and indirectly all the organs of the body. There are involved here the rest of the motor neurones in the brain and spinal cord, the motor end-plates on the skeletal muscle fibers, the skeletal muscles, the tendons, the joints and their ligaments, membranes and secreting surfaces, the heart and circulation organs, the respiratory organs, the vasomotor organs, the suprarenal bodies, Islands of Langerhans, and possibly other endocrine glands, the blood manufacturing glands, the sense organs, afferent neurones, and association neurones connecting all these organs with the central neurone system, the skin, kidneys, liver, and probably other excretory and secretory organs.

The voluntary motor system does the work of the individual and the work of the race. The possibility of voluntary movement has made mind. The utility, development, and progressive efficiency of the human voluntary motor system has evolved in company with the production, improvement, and perfection of the human mind and its functions.

Rational rest of the voluntary motor system is essential to the health of us all. But the problems of rest for the voluntary motor system are of greater importance in the life of the laborer and in the business of the employer of labor. The widespread investigation and discussion of "fatigue and efficiency" can serve a useful purpose only in so far as it may discover and apply the laws of rest that govern efficiency.

Rest of the voluntary sensory systems.—A sensory system in-

volves receptor organs, afferent neurone chains, association neurones, and related efferent neurone chains. Such a system is intimately related to the organs of other bodily systems. All the sensory paths lead to the brain. They all serve the mind. All sensory systems are dependent on other systems of organs for protection, nutrition, removal of wastes, etc. Providing rest for a sensory system is therefore not a mere local matter.

The most prominent voluntary sensory system is the visual system. Vision is a mental state, a feeling, produced by the combined co-operating, and integrating, services of a large number of organs that constitute the visual apparatus. These organs include, among others: voluntary muscles that protect the eyes and direct their movements; involuntary muscles that regulate the supply of light within the eye and assist in focussing the lens; blood vessels; lymph vessels; solid and liquid transparent, transmitting and refracting media; and complicated receptor organs in the retina that analyze and classify light vibrations received from the focussing apparatus of the eye and transmit them to the brain through afferent neurone chains.

Resting one's eyes is therefore a provision of rest for all the component parts of one's eyes, some of which are probably more sensitive to fatigue than others. Eye strain and eye fatigue is a complicated condition common with people that do a great deal of eye work. Eye strain and eye fatigue are commonly magnified by visual defects and increased by faulty habits of reading and writing and other forms of bad hygiene.

Rest of sensory systems may be secured by excluding the receptor organs of those systems from stimulation. We may exclude disturbing noises, repulsive odors, excessive heat or cold, uncomfortable pressures, and sources of pain.

Rest of conscious mind.—Conscious or intelligent mind is a product of the neurones of the cerebral cortex. The anabolic and katabolic processes of some nine thousand million neurones are basic to the phenomena of mind. Every neurone has a number of terminal axis-cylinder process, collateral, and dendritic branchings that form synapses with the branchings of other neurones. It is thought that in some way the metabolisms that take place in these infinitely numerous cortical synapses may produce mind.

The cerebral cortex is in communication with all the organs and cells of the body directly and indirectly by way of the afferent

association and efferent neurone chains described in our chapter on play. The cortex of each cerebral hemisphere is a composite of many neurone regions or nerve centers, each one of which is concerned with receiving nerve impulses from a certain part or certain parts of the whole body, the brain and spinal cord included; or with transmuting those incoming nerve impulses into feelings, emotions, instinctive reactions, memories, ideas, judgments, impulses, or the will-to-do; or with the development of efferent nerve impulses that are transmitted to appropriate organs that are stimulated thereby to perform their normal functions. The brain and the spinal cord have a great many neurone centers or nerve centers that are called lower nerve centers. These lower centers are not parts of the intelligent mind but rather parts of what have been called the unconscious mind, the subconscious mind, the instinct mind, the reflex mind, the automatic mind.

The activities of the hundreds of billions of synapses in the human cortex cerebri are concerned with producing the phenomena of intelligent reflective mind. Higher mental activity is activity of the cortical synapses and is intimately dependent upon the supporting activities of an infinite number of lower nerve-cell centers and upon the supporting service of the great co-operating integrating organ systems of the body as a whole.

The products of higher mental activity, the services of the cortical centers, give us consciousness. These products supply us with feelings. It is said that there are some fifty thousand elements that enter into our sensations, but all our feelings are of two qualities. They are either pleasant or unpleasant, satisfying or dissatisfying.

Hence the requirement for mental rest is made known by unpleasant feelings. We cannot always depend upon our feelings for accurate information. Sometimes mental rest is required, but the feelings that should urge for rest do not appear.

The needs for mental rest are products of the causes of the need for cell rest discussed in the earlier pages of this chapter, particularly those discussed in the fourth and fifth groups.

The production of mental rest is accomplished by means of our voluntary and involuntary controls of rest already discussed in this chapter. It is important to re-emphasize here the necessity of excluding from the mind, if it is to rest, all exciting, depressing, worrying, dissatisfying influences.

The effect of mental rest is to produce feelings of comfort, interest, pleasure, and satisfaction in place of those of dissatisfaction, weariness, sleepiness, headache, or pain.

The unsatisfied need for nervous and mental rest is a very important source of poor nervous, mental, and bodily health. (The three effects are never wholly separable.) These unsatisfied needs for mental rest may be evident in constant small movements of the hands, fingers, and feet; in exaggerations of the importance of unessentials in daily life; in persistent and groundless fears, anxieties, constant worries, continuous mental excitement, chronic regret, depression, and similar signs and symptoms of poor mental health.

Mental rest is a product of interesting work, happy play, pleasing exercise, peaceful sleep, balanced nutrition, and effective excretion.

The cultivation of the power to relax, and of mental tranquillity, cheerfulness, repose, interest in one's work, and pleasure in one's recreation and play are the determining factors in mental rest.

Constructive values of rest.—The preceding pages of this chapter present facts that have been proved through the researches of a very great many men and women. Future research will amend or re-interpret some of these facts, but the principles of cell chemistry and of cell thermodynamics upon which the text of this book has been constructed will not change. These facts prove the following constructive values of rest in relation to human health:

1. Rest promotes growth.
2. Rest promotes repair and replacement.
3. Rest makes possible the restoration of mental, nervous, and physical energy.
4. Rest promotes the restoration of function.
5. Rest makes mental health possible.
6. Rest safeguards life and makes its continuation possible.

Place of rest in constructive hygiene.—A balanced program of constructive hygiene makes rational adjusted provision for nutrition, excretion, exercise, work and play, defense, and rest. The place of rest in such a program is determined by the logic of the laws that we have been discussing. We know that the rate of the

expenditure of energy must not long exceed the rate of the accumulation of unused energy. We know that the expenditure of energy should not be out of proportion with the stimulus. We know that the rate of the formation of fatigue products must not exceed for long the rate of the removal of fatigue products. We know that the rate of wear, tear, and depreciation must not long exceed the rate of repair and replacement. We know that destruction must not for long exceed construction. And we know that the body is a whole and not a combination of independent parts obeying separate laws. It is convenient to refer to mental hygiene and physical hygiene, to the rest of mind and the rest of body; but mind and body, mental and physical, are inseparable. Each must include the other. The logic of these laws of rest applies to mind and body at one and the same time.

For these reasons a constructive hygiene program to govern daily life should make the following provisions for rest:

First, the pressure of occupation should not demand an exhausting expenditure of energy, either chiefly physical or chiefly mental. The rest-as-you-work adjustment should be so made or regulated as to secure a maximum productive output without excessive fatigue.

Second, wholesome objectives and incentives should be utilized to remove the monotonies or repugnances of occupation, thus giving it the absorbing interest of play.

Third, a period of rest and relaxation should follow each meal, particularly the heavier meals.

Fourth, each day should furnish a period of vigorous physical exercise and play that brings rest because it utilizes muscles and mental functions different from those employed in the day's work.

Fifth, each night should furnish adequate peaceful sleep.

Sixth, each week-end should furnish rest in the form of satisfying and preferably vigorous activities that differ largely from those of the preceding week's work.

Seventh, occasional vacations in which there is a change of surroundings, a change of activity, a large substitution of wholesome vigorous play for routine work, and a proper regard for sleep, big-muscle exercise, and balanced nutrition are often important rest-factors in the program of the year.

CHAPTER XVIII

THE CONTRIBUTORY CAUSES OF HEALTH: RESPONSIBILITY FOR HUMAN WELFARE, CONTROL OF ENVIRONMENT, PREVENTION OF HEALTH-INJURY

The preceding chapters in this book have been devoted to a consideration of the major, direct, or determining causes of health. Those causes are the physiological and psychological principles that finally decide the health of the whole body with all of its organs and all of their functions. Briefly, those major or direct causes are: (1) a heredity that furnishes all the organs of the body with capacities for the development of enduring energy, functional efficiency, and longevity; (2) a nutrition that prepares and utilizes adequately all the chemicals necessary for the growth, repair, energy, and functional service of the whole body; (3) excretion that efficiently removes the rejections, wastes, and refuse of organic activity; (4) appropriate and adequate physical exercise that stimulates organic and functional development and maintains bodily condition; (5) interesting work and happy play, mutually adjusted to physiological and psychological age, that develop and maintain body, mind, personality, and character; and (6) satisfying rest that maintains mental serenity and makes possible the reinvigoration of mind and body. No one of these dominating causes alone brings health. All must work together as causes. Defects or deficiencies in any one of them make the achievement or maintenance of health more difficult, or they damage health, or they destroy health. Furthermore, the successful production of health by these major constructive sequences of cause and effect depends upon the support of certain indirect but essential influences. These requisite, indirect, constructive causes of health may be designated as contributory causes of health. They may be defined in general as the conditions and influences that make it possible to satisfy the requirements of the determining causes of health and thus enable those determining causes to operate beneficially.

Responsibility for human welfare.—The responsibility of the individual, the family, and society for human welfare and particularly for the welfare of dependents is the first contributory cause of health. From the urge of this cause has come all the

progress that has been made for and in the improvement of human health throughout the ages. This pressure for the protection and improvement of health arises out of: (*a*) the instinct for self-preservation; (*b*) the parental or "mothering" instinct; and (*c*) the gregarious or herd instinct.

Individual responsibility for health.—(1) The primitive self-centered concern of the individual is for his own personal safety. This is an inherited instinct for self-preservation. There is a long way between the fear, flight, and defense reactions of primitive people and children concerned with personal safety and the health-building and health-defending program of the mature, intelligent individual of today. But both types of concern have to do with the welfare of the individual. The realization by the mature individual of a responsibility for his own health today is an educated, intelligent, slowly accumulating, refined product of the pressure of the instinct for self-preservation that has been worked up through a great many yesterdays. With the growth of reason and the increase of knowledge concerning individual health, with its constructive factors, its destructive factors, and its defenses, the "fear, flight, and defense-reactions" of our primitive ancestors and of our childhood have developed into a more rational and intelligent recognition of individual responsibility that may be satisfied through the measures and habits of modern individual hygiene.

(2) The concern of the individual with his own welfare has developed in order that he may better serve others. Every mature person carries a responsibility for the welfare of dependents. It may be for a mother or father, a wife, an infant, an immature brother or sister, or an invalid in the family, or some other more or less helpless dependent.

And every mature person carries a responsibility for the welfare of the community of which he is a part. The intelligent, rationally educated individual recognizes that obligation and plans to meet it.

These responsibilities of the individual for the welfare of his dependents and for the welfare of his community combine to put upon him an obligation to build, maintain, and safeguard his own health so that he may better meet those responsibilities. The recognition of such responsibilities as these and of the obligation to be ready to meet them is a slow, frequently interrupted product

of civilization that had its beginning in the individual, household, and tribal relations many thousands of years ago.

A realization of individual responsibility for health, then, is a force working for better individual health in the service of the individual himself, in the service of his family, for his dependents, and in the service of his community. This responsibility has been a persistent pressure on the individual through the ages, urging him to find more successful methods of self-preservation.

Group responsibility for health.—The history of the family is a history of conditions, customs, and procedures that have grown up to satisfy the family responsibility for group welfare. The family group came out of prehistoric conditions for the protection and benefit of its members, adults and children, competent and dependent. It grew naturally out of the parental or "mothering" instinct and has been a perpetual urge for better measures and means for more completely safeguarding the family group. This pressure in the process of ages has led on to a recognition of the added safety and better protection given by association with other family groups. With a realization of the power-value of this relationship came a recognition of responsibility by one family for the welfare of the other family.

Intergroup (*i.e., public*) *responsibility for health.*—The association of related families in the prehistoric affairs of primitive man, the ancient organizations of clans and tribes, the later formation of confederations and alliances, and the more recent building of empires, typical of intergroup relations, are based on the safety values and welfare values of the herd instinct that drew the primeval community together. The family group is stronger than the individual. The association of families into communities forms an intergroup relationship that brings greater power than that of the family. The clan, the tribe, the nation, and their organized social and political equivalents are intergroup organizations that furnish power with which the individual, the family, and society may better meet their responsibilities for health.

Favorable environment.—Each favoring factor in the environment is a constituent, contributory cause of health. An environment is favorable to health if it furnishes conditions and influences that support the determining causes of health and if it contains few or no conditions or influences that interfere with the operations of those causes. Primitive people with no knowledge

of the causes that produce, maintain, improve, injure, defend, or restore health were always at a serious and tragic disadvantage in an unfavorable health environment. Primitive people, therefore, flourished best in climates in which the vicissitudes of seasons and weather were not serious and the influence of sunshine, temperature, and humidity were equable. They flourished only in regions that furnished ample supplies of food to eat and water to drink. If either were difficult to secure, health and life were correspondingly difficult. They flourished best in regions in which the soil and drainage were unfavorable to the insect and animal causes and carriers of disease germs. They flourished best in an environment free from inanimate and animate enemies of health and of life.

These ancient environmental requirements were furnished only by nature. Man had but little control over his environment. Today a favorable environment may be the product of scientific information applied by rational education, paid for in the currency of the realm, demanded by public opinion, and maintained by governmental power.

Rational control of environment.—The power to manage and control environment enables human beings to meet their health responsibilities more effectively by maintaining those conditions and influences in the environment that support the determining causes of health and by counteracting or removing those conditions and influences in the environment that are unfavorable to the operation of the determining causes of health. Each factor that serves to give a part of this power to manage and control environment is a constituent contributory cause of health. These constituent factors are: (1) the power of scientific information; (2) the power of rational, balanced education; (3) the power of economic resource; (4) the power of government; and (5) the power of public opinion.

Scientific information.—The responsibility for individual health, for family health, and for public health has been a compelling influence pressing men and women, families, communities, and nations to search for, find, and use better ways and more adequate means of satisfying their responsibility for health.

Hunger, that made hunters, fishers, and berry-pickers of our remote ancestors, has given us today quantitative and qualitative scientific stock-raising, fisheries, agriculture, and other highly developed forms of scientific food production. Scientific research,

experience, and invention have enabled mankind to meet its nutritional requirements in countries and climates where inadequate supplies of foodstuffs were barriers to health and life for those remote ancestors.

Thirst, that forced primitive man and all the plant and animal life about him to live and search for food always near water, has given us scientifically constructed systems of driven wells, reservoirs, and irrigation today that permit us to live healthfully far away from the natural limits of water-supply. They enable us, too, to maintain an available supply of water for domestic, agricultural, and stock-raising purposes despite the adversities of irregular and "dry seasons." The desert has been transformed into gardens and grain fields, and herds are found today in regions that were arid and uninhabitable before scientific information gave man the power to make them produce food-plants and food-animals and thus contribute to his nutritional requirements.

The vicissitudes of climate, seasons, and weather that limited man for so many centuries to those parts of the world that were naturally of a comfortable and endurable temperature, sunshine, and moisture have given us scientifically constructed houses of wood and stone that enable us to live almost anywhere. The cave, the hut, and the tent of skins with a faggot fire have given place to homes that are heated by scientifically devised fireplaces, stoves, furnaces, steam pipes, and hot water systems. Scientific information has given us windows for light and ventilation; plenum and vacuum ventilation systems; and oil, gas, and electric lights. The "fig-leaf" and animal skins that covered the nakedness of the first men and women and gave them but little protection against the severities of frost, snow, and ice are displaced by garments made with appropriate reference to climate, seasons, and weather in accordance with the teachings of science. The power of scientific information has enabled man to control these unfavorable factors in his environment and thus live and have his health in climates, seasons, and weathers that were full of hazard for his distant ancestors.

Superstition, mysticism, misinformation, and tradition concerning the sequences of cause and effect that produce, improve, maintain, damage, and restore health have dominated the thoughts and actions of mankind throughout the ages. Accurate information concerning physics, chemistry, and the biological sciences is of

recent origin. There could be no extensive rational hygiene without this scientific information. Mankind could go only a short way toward satisfying the constant responsibility for health without it.

With the perfecting of magnifying lenses, the invention of the compound microscope, the discovery of the principle of sub-stage illumination and of the Abbé condenser, means were provided for research into the world of invisible structures and organisms within the last two hundred years. The methods of scientific research devised for investigation in the fields of physiology, psychology, biology, bacteriology, zoölogy, physics, and chemistry, in the last century, have placed hygiene on a rational basis. Our rapidly growing scientific knowledge has already given mankind a new, powerful, and increasing control over the hygiene of his environment. The accumulated ignorance of the everlasting past concerning the real nature and meanings of health and disease is disappearing, slowly in some respects, more rapidly in others. The power of scientific information is contributing effectively to the advancement of human health.

Education.—Rational, balanced education is a constituent contributory cause of health because it applies scientific information appropriately to the needs of man and thus utilizes that power to manage and control environment.

The modern addition of the natural sciences to the educational curriculum has tended to balance and rationalize education. With improved methods of teaching, this balancing and rationalizing influence will be more complete. The superstitions that persist from the uninformed past will give way, as so many of them have already given way, to the compelling arguments of truth. Backed by a balanced education, the individual, the family, and the public are in better position to form rational and discriminating judgments in matters of health. They are in better position to meet their health obligations.

There is more health, less sickness, and there are fewer deaths in the earlier and middle age periods in educated communities than in illiterate communities.

The power of rational education, applying scientific information, has counteracted certain inherited and removed or counteracted certain inanimate and animate causes of disease, certain of the carriers of pathogens, and certain of the contributory causes

of disease in enlightened communities in all parts of the world. It is this power that improved the health of Cuba, the Panama Canal Zone, and the Philippine Islands in recent years. It is this power that has postponed the average age of death in the enlightened nations of the world so that men and women live longer today than men and women lived fifty years and even twenty years ago. It is this power over environment that has reduced the occurrence of smallpox, typhoid fever, malaria, yellow fever, and cholera in the United States. It is the power that reduced the occurrence of syphilis and gonorrhoea in the American Army during the Great War to the lowest record ever made by a large army.

Economic resource.—The power of economic resource is a constituent contributory cause of health. Economic resource is the basis of purchasing power. It establishes credit and makes funds available with which to meet the expenses of those applications of scientific information for the management or control of environmental conditions and influences which rational, balanced education recognizes as important for the acquisition or conservation of individual, family, or community health. These applications are made by individuals, by groups, and by communities.

1. The economic resource of the individual enables him to purchase health. With money or credit, the individual buys food, clothing, home, and home conditions, and recreation and play which his information, judgment, and economic resource select. Scientific information and rational, balanced education influence the individual to invest his resources in purchases that appear to satisfy his health responsibilities and promise comfort, happiness, safety, and longer life. The individual does not ordinarily consciously attempt to buy health until he finds his health has been injured. But one can easily note, on analysis, that a large proportion of the cost of living goes to pay the cost of the management and control of those conditions and influences which we have described as necessary to the successful operation of what we have called the determining causes of health. This is particularly obvious in connection with the expenditures made by men and women whose health deterioration has become evident to them.

The individual who satisfies his responsibility for the welfare of his dependents meets that responsibility, in part at least, by virtue of his power to pay for the cost of those measures which

his education and information select for the satisfaction of that responsibility. These costs may be classified as (*a*) the cost of a balanced, adequate food ration adapted to the health requirements of infancy, childhood, youth, maturity, old age, or invalidism, as the case may be; (*b*) the cost of provisions for and programs of fitting physical exercise, recreation, and play; (*c*) the cost of conveniences and conditions insuring physical and mental rest; (*d*) the cost of protection from the agents and conditions that injure health; (*e*) the cost of the remedial treatment of those who are sick; and (*f*) the cost of the rational, balanced education of younger and maturing dependents, preparing them to meet more successfully their coming obligations as parents and as citizens.

2. The economic resources of the group supply a power to purchase health for the constituent members. The family group, school group, occupational group, and institutional group all contain dependents of one type or another under authoritative, responsible maturity. The health welfare of the group, whatever the group may be, is subject to the purchasing power of the group exercised by way of this authoritative, responsible maturity that represents the group. When and where the scientific information and the rational, balanced education of a group is accompanied by the resources with which to buy and make investments in accordance with that scientific information and rational education, the expenditure always brings better group health.

3. The economic resource of the intergroup entity has a greater health-purchasing power than the group or the individual. The intergroup organization has a greater economic resource than the group organization, even as the group possesses a greater economic resource than the individual. It is the organized and unorganized purchasing power of the people of a village, town, or city, a county, a state, or a nation that draws to their markets a varied and complete supply of foodstuffs from near or distant sources, that builds their great systems of water supply and sewage disposal, that buys and maintains their parks and playgrounds, that builds and maintains their schools, colleges, and research institutions, that buys community protection against the agents and influences that damage and destroy health, that supplies institutions and measures for the treatment of disease, and that enforces the health and other welfare laws enacted for the common good.

Government.—The power of government is a constituent contributory cause of health. Organized government can mobilize the scientific information, the rational education, and the economic resource of its people for the common good. The power and authority of enlightened government has done much to manage and control environment, maintaining and improving the factors that are favorable to health and counteracting and removing those that injure health. It is only through the process of legislation and governmental enforcement of legislation that the people as a whole, the public, can secure the benefits of scientific information, rational balanced education, and the power to purchase effective, constructive, defensive, remedial, and aggressive hygiene. The achievements of scientific information and rational balanced education described in preceding paragraphs would have been impossible without the initiating, supporting, and enforcing power of the governments involved.

Public opinion.—The power of public opinion is a constituent contributory cause of health. The persistent opinion of the majority eventually dominates the practice of the public and compels supporting governmental legislation and secures effective law enforcement. The public eventually gets what it wants. A public that is influenced by scientific information and rational, balanced education will mobilize its legislative, executive, police, and financial powers—its powers of government—for the improvement and conservation of the public health.

Prevention and care of health-injury.—The power of mankind to remove or alleviate health injury and to overcome its damaging effects is the product of a number of factors. These factors are the same as those that produce the power to control environment. They were classified above as (1) the power of scientific information; (2) the power of rational, discriminating judgment, the product of balanced education; (3) the power of economic resource; (4) the power of government; and (5) the power of public opinion.

The medical sciences are furnishing us with a steadily increasing amount of accurate information concerning the treatment of health injuries. The balancing process that is going on in our scheme of fundamental education is giving us an advancing rationalization of judgment in the applications of those facts. Individuals and families possessed of rational, balanced education are

in growing numbers using their economic resources for the purchase of relief from health injury. County, city, state, and national governments are using, more and more, their available scientific health information and their rational health judgment for the enactment and enforcement of laws, and for the building, equipment, maintenance, and selection of personnel of hospitals, clinics, dispensaries, and other institutions for the treatment of health injuries. And the great public with its heritage of superstition and credulity is becoming slowly, very slowly, possessed of scientific information concerning the general principles of remedial hygiene and is slowly, very slowly, acquiring a general balanced education with which to exercise rational, discriminating judgments in the selection and employment of remedial health service.

Our progressing power to treat health injuries scientifically, and the mounting contributions of improved health and of restored health that this power is making are shown in a long and continually growing list of diseases that are more successfully treated today than ever before. There is a large number of diseases that are not yet treated successfully. Science has not yet furnished us with the information necessary for their rational treatment. But this list is slowly growing smaller.

Perhaps the most dramatic illustration of the health contributions made by the rational treatment of health injury is shown by a comparison between the modern and the previous treatment of the mental injuries that we call insanity. The ancients regarded insanity in its various types and degrees as a product of supernatural control. Either a god or a demon inhabited the mind or controlled the mind. This demonological conception of insanity was supplanted for a short time in Greece by the rational teachings of Hippocrates, about 460 B.C. This great man, the Father of Medicine, taught that insanity was due to some disturbance of the brain. But the scientific methods of Hippocrates were forgotten during the period of medieval history. The Dark Ages were saturated with mysticism and superstition. The demonological conception of insanity became again the common belief. For a thousand years or more supernatural agencies were as a matter of course accepted as causes of insanity. Abnormal mental phenomena were attributed to holiness, witchcraft, and malignant demons. If his abnormal mental activities were in conformity with the reli-

gious teachings of the time, the individual was regarded as holy. If those activities were not in such conformity, he was rated as one possessed of evil spirits. Witchcraft occupied a prominent place in the thoughts and concerns of the people of that period. The witch trial became an accepted method of treating persons suspected of witchcraft. These trials were held well into the eighteenth century. The penalty was death. In the principality of Treves, within a period of several years, it is reported that 6,500 persons were executed after trial for witchcraft. Many of those persons would today be classified as neurotics or insane.

During the eighteenth century, science and humane standards began to displace the demonological conception of insanity. The insane were no longer looked upon as possessed of devils. But for a time their treatment was most irrational and inhuman. They were no longer burned at the stake, but they were confined in dark, damp, loathsome, infested dungeons, fettered by chains, and cared for by convicts.

Late in the eighteenth century and early in the nineteenth century, the treatment of insanity had come again to be in general accord with the teachings of Hippocrates. At that time two hospitals, the first of their kind, were provided for the insane in London. Others were then established elsewhere. Chains and dungeons were abolished. Treatment was attempted along rational lines. A division of medicine, called psychiatry, came into being. During the last one hundred years this branch of medical science has made great and significant progress, and the treatment of injuries to mental health has been placed upon a scientific basis. Within the present generation, physiology and psychology have furnished psychiatry with scientific information that is in brilliant and convincing contrast with the irrational demonological conceptions of our forefathers. The demonstration of the efficacy of this modern treatment of mental health injuries in the American Army during the Great War was strikingly successful.[1] But despite these scientific and consequent humanitarian advances that have been made in the treatment of mental diseases, and despite the fact that a larger number of mental health injuries are relieved today than ever before in the history of mankind, it remains true that a far

[1] Patterned after chapter on "History of Insanity," in *The Psychology of Insanity,* by Bernard Hart, Macmillan, 1925.

greater percentage of cases of these diseases are still beyond our reach than are within our control. The scientific information and the educated intelligence of the future will add enormously to this field of remedial hygiene.

The power to remove health injury and the power to overcome its damaging effects are nowhere contributing more to the sum total of human health than in the field of modern surgery. Here the scientific information that has been secured concerning anesthesia, antisepsis, asepsis, and surgical technique has been combined with scientific anatomy, physiology, pathology, and diagnosis, to safeguard and save human health and human life with brilliant and consistent success.

CHAPTER XIX

THE PRACTICE OF CONSTRUCTIVE HYGIENE

In the preceding chapters, it has been shown that the maintenance and improvement of health is a joint product of determining and contributing principles. These are the principles of constructive hygiene. The determining principles have been described as (1) heredity, (2) nutrition, (3) excretion, (4) physical exercise, (5) play, and (6) rest. The contributory principles have been described as (1) the responsibility of the individual, the family, and the public for health, (2) favorable environment, (3) the power to control environment, and (4) the power to alleviate health injury and overcome its damaging effects.

The applications of the laws established by these principles of constructive hygiene for the improvement and the maintenance of human health may be discussed in terms of the practice of (1) constructive individual hygiene; (2) constructive group hygiene; and (3) constructive intergroup (i.e., societal) hygiene. A consideration of the practice of hygiene belongs to another text. Only a brief preview is appropriate here.

Constructive individual hygiene.—The first constructive hygiene of the individual is the hygiene given him by his parents. All of his capacities for physical and mental growth, for longevity, for the development of energy, efficiency, and educated intelligence, for the formation of character and personality came to him with his parental gift of life. These capacities were potential in the microscopic chromosomes furnished by the paternal germ-cell and by the maternal germ-cell that combined to form the fertilized ovum that gave him his life and his heritage. During his years of infancy, childhood, and dependent youth whatever of constructive hygiene there may have been in application for the development of those native capacities was the hygiene given him by the responsible adults and co-members in his family-group, play-group, school-group, and community. From these sources, during his years of dependency, came all the scientific information, rational, discriminating judgment, purchasing power, custom, legislation and law enforcement, example, guidance, or education that may have been in operation, planned or unplanned, for his health production, health maintenance, or health improvement.

Constructive individual hygiene therefore does not appear until the individual becomes independent or, at least, relatively independent. It arrives slowly because the transition from dependency to relative independence is as gradual as the development of infancy into maturity. The constructive individual hygiene of the adult, obviously, must be built up on the products of the hygiene of his dependency. The success of the program of constructive hygiene of the adult therefore depends in any given case upon the prior satisfactions of the pertinent health responsibilities of the parents, the other members of the home group, other organized groups, the community, and the government under the influences of which the individual develops from infancy to maturity.

If the hygiene of the years of dependency has not been seriously defective or deficient, a rational program of adult constructive hygiene will succeed in maintaining, improving, or restoring health. The details of such a program of constructive individual hygiene are to be given in another text. Here it is our purpose to indicate only the composite requirements that must be met by the mature individual in his program for the maintenance or improvement of his own health.

The first requirement of constructive individual hygiene is that the adult shall understand his health responsibilities. The self-developing and self-conserving adult must examine, measure, and condition himself to meet his responsibilities for the improvement or maintenance of his own health and for the improvement or maintenance of the health of his dependents and of his community. His health welfare is dependent upon the health welfare of his family, his occupational group, and his community. Conversely the health welfare of his family, his occupational group, and his community is dependent upon his health welfare. There is a mutual reciprocal responsibility. There are responsibilities of the adult for the health of the mate that is to be and for the children that are to come. Every normal man and every normal woman should prepare for a mate, a home, and a family. And every adult should play his responsible part in the maintenance of the health welfare of society, of which he and his dependents are necessarily beneficiaries and to the strength or weakness of which he and they are inevitably contributors. These requirements cannot be met unless the individual consciously recognizes his responsibilities and is prepared physically, mentally, and spiritually to meet them.

The second requirement of constructive individual hygiene is that the adult must have power to manage and control his environment. This power must be: (*a*) for the acquisition, maintenance, and improvement of conditions favorable to the conservation or betterment of health; (*b*) for the removal or control of conditions unfavorable to health; and (*c*) for the removal or alleviation of health injuries and their damaging effects. This composite power over environment is supplied, as we have noted previously, through (1) scientific information, (2) rational balanced education, (3) economic resource, (4) government, and (5) public opinion.

The responsible adult can meet his obligations only in case he is in possession of a sufficient amount of scientific information and educated intelligence to enable him to formulate rational judgments in matters of policy that relate to the management and control of environment in the interest of his health obligations to himself, his family, his occupational associates, and his public. And his scientific information and rational judgment must enable him to select with discriminating intelligence the scientific health advisers to whom he should go for the dependable health advice and service that he himself is not competent to give.

But the management and control of environment is expensive. Rational balanced education, scientific information, and scientific service are costly. And food supply, water supply, housing, clothing, recreation, play, rest, and schooling are expensive, particularly in urban centers of population. And purchases such as these must be made by the individual for the satisfaction of his responsibilities for health. The successful adult has acquired sufficient economic resource as a rule to meet the ordinary expense of constructive hygiene for himself and in contribution to the group and public of which he is a part. His family-group, occupational group, local community government, and public opinion must make the larger and extraordinary investments necessary for the satisfactory management and control of the important favorable and unfavorable environmental factors that are outside his personal economic reach. Within reasonable limits the individual adult who has made an average success in the affairs of life may purchase his own advantages and satisfactions in constructive hygiene. These reasonable limitations are established by the purchasing power of his group and his community in relation to such enterprises as the transportation and marketing of foods, the con-

struction of systems of water supply, the safeguarding of agriculture, stock-raising, and shipping through weather bureau warnings, the building of sewer systems, and the making and maintaining of parks and playgrounds.

The third requirement of constructive individual hygiene is that the individual adult must practice satisfactory habits of constructive hygiene. These constructive health habits are, logically, (1) habits of adequate, balanced nutrition, (2) habits of effective excretion, (3) habits of regular, vigorous, attractive physical exercise, (4) habits of interesting work and proportionate habits of satisfying play, and (5) habits of tranquilizing mental and physical rest achieved through recreation, relaxation, and sleep. These habits of constructive individual hygiene meet the requirements established by the determining causes of health, utilizing for the purpose the contributory causes of health. These habits are programs of individual conduct that must be followed in obedience to the determining laws of constructive hygiene if good health is to be achieved or maintained or if the quality of health is to be improved.

Constructive group hygiene.—The significant entities in group hygiene are the family or home group, the school group, the occupational group, and the institutional group. The most important and the most complete group is the family group. Our brief discussion here will be concerned largely with the constructive hygiene of the family. The principles emphasized here will be applicable, with logical readjustments, to the constructive hygiene of the school group, the occupational group, and the institutional group.

The strength of group hygiene lies in the constituency of the group. A membership that includes educated maturity, appreciation of health responsibility, pertinent scientific information or a knowledge of where to go to get that information, and adequate economic resource will furnish a high power and quality of constructive group hygiene.

The weakness of group hygiene lies in the helplessness and vulnerability of the dependents in the group. To a degree, every member of a group is dependent upon every other member for his health achievement, protection, and defense. But the complications of infancy, childhood, youth, senility, and invalidism, and the precious privileges of matrimony, child-bearing, motherhood, and

fatherhood present problems in the constructive hygiene of dependency that are of paramount importance to the health of the individual, the family, and the public. It is for the solution of these problems that the group formulates and operates, or should formulate and operate, a calculated policy and program of hygiene with very special emphasis upon its constructive factors. Unfortunately the hygiene of the group is ordinarily not a product of conscious thought or plan. Problems are met or unresistingly received as they arise, with little or no provision or constructive, preventive planning.

It would seem self-evident that the conscious applications of the laws of constructive hygiene should be a common and prominent factor in the policy of every group, most certainly for every family group. It would seem self-evident that such an application should include: (1) an analysis of group responsibilities for the maintenance and improvement of the health of all its members and a deliberate, calculated group preparation to meet and satisfy those responsibilities; (2) a cultivation of those constituent powers that furnish the composite power to manage and control environment for the maintenance, improvement, and restoration of health; and (3) a training and education program and a program of experiences appropriate to each age period and to each variety of dependency in the group that will encourage, establish, and maintain individual and group habits and policies of constructive hygiene. These inclusions of constructive group hygiene should be emphasized quite as much as the more common emphases that are made in the interest of defensive group hygiene—a subject of later consideration. Such experiences in babyhood, childhood, and youth would yield the fullest realization of nutritional and growth possibilities. These eighteen years of safeguarded dependency, characterized by vigorous, developmental, interesting physical exercise and by happy, joyous, and constantly but unobtrusively guarded play would produce men and women of fine bodies and wholesome stable minds whose physical and mental health expectancy would reach out toward vigorous old age. There would follow a greater probability that the adult product of the family program of hygiene would be in vigorous, effective health and in the habit of intelligently conserving that health. This adult product would be more likely to prepare for marriage with a rational respect for constructive heredity. The adult product

would be in better position to manage its program of adequate, balanced nutrition, effective excretion, interesting exercise, attractive work and satisfying play, and reinvigorating rest, for the maintenance and improvement of its own health and for the health welfare of the dependents for which every adult must expect to be responsible.

Constructive intergroup (i.e., societal) hygiene.—The entities included here under the term "intergroup" are the associations of family groups and of the other groups that form communities and governments. These associations of groups constitute rural, village, and city communities, and town, city, state, and national governments. They constitute society.

The strength of the intergroup entity resides in its power to mobilize adult responsibility, educated, intelligent judgment, scientific information, economic resource, legislation and law enforcement, and public opinion. With these resources the intergroup power over environment is far greater than the power of the group or of the individual. And intergroup responsibility for human welfare has in the process of the ages become greater than that of the group or the individual. But the responsibility and the power of the community and its government are the results of the orderly arrangements of organized society that have arisen for the welfare of the individual, even as the individual is conversely responsible for the welfare of the intergroup entity of which he is a part. The plan and policy of constructive intergroup hygiene is therefore an application of organized collective power for the health welfare of its individual and group constituents.

For these reasons the powers and the resources of communities and their governments are being used more and more for the practical applications of the laws of constructive hygiene. Education has become a governmental function. Schools, colleges, and universities are founded and maintained by the various types of communities and governments, and the curriculums of these educational institutions are furnishing an increasingly higher degree of thought-producing, judgment-cultivating education. And the curriculum is slowly, interruptedly perhaps but nevertheless surely, increasing its content of constructive hygiene along with its increase in defensive hygiene. Scientific research is receiving greater and greater encouragement and our consequent knowledge of the laws of constructive and other hygiene is growing. Huge expendi-

tures are legally authorized and directed toward the extension and improvement of man's control over the factors in his environment that contribute to the maintenance or improvement of human health. Communities and their governments have no direct power to produce individual or group habits of constructive hygiene. But these intergroup entities can and do exercise their powers to make it more easily possible and practical for the individual to understand and practice wise habits of nutrition, excretion, exercise, work and play, and rest. And there is a growing public concern over the conservation of sound heredity and prevention of the transmission of defective and deficient heredity.

Intergroup constructive heredity.—Laws have been enacted in various states for the control and termination of hereditary transmissions of various forms of insanity. These enactments have not as yet proved their practical utility to the point of wide application. But their purpose is of very great importance in the field of constructive hygiene. Any procedure that suppresses the transmission of defective or deficient heredity inevitably conserves sound and complete heredity.

Intergroup nutrition.—Communities and their governments have been applying their educational, scientific, and economic resources, as long as they have had such resources, for the maintenance and improvement of their food supply. Our own national and state governments have made the production, preparation, transportation, and marketing of foods matters of continuous legislative and executive concern. Farming, dairying, stock-raising, fisheries, milling, canning, packing, freighting, and marketing are established governmental concerns, for the scientific study and productive assistance of which, enormous governmental investments of brains, energy, and money are of regular annual routine. These activities and those that reclaim land and make it fertile for farming or stock-raising, or dairying, that construct great irrigation projects, that build waterways and transportation facilities, and in other ways secure greater control and more effective management over man's nutritional environment are governmental applications of constructive hygiene for the benefit of the governed. These are solutions of intergroup problems of nutrition far too great for the individual or the group to solve and that are handled by the more powerful intergroup entity for the health welfare of the individual and his group.

Intergroup excretion.—The sanitary disposal of community sewage has become an imperative and often a colossal intergroup obligation. The separation of sewage disposal from water supply is a problem of defensive hygiene and belongs to another text. Its relation to constructive hygiene is, however, obvious. This statement is equally true with reference to the prevention of sewage disposal from becoming a breeding- and feeding-place of insect and animal carriers of pathogens. This subject also will be considered in another text.

Intergroup physical exercise.—Within recent years the growth of intergroup provisions for physical exercise has been phenomenal. Parks, playgrounds, athletic fields, recreation centers, bathing-places, boating provisions, public forests, and other public, community, and governmental investments for more and better physical exercise have been made in all parts of the United States. Thirty-four states had laws in 1923 requiring more or less physical training in their elementary and secondary schools. The central emphasis in physical training is physical exercise.

Intergroup play.—Community and governmental interest in play is usually an intimate part of an interest in physical exercise. Physical activity, recreation, and play are in the main inseparable. The recreations and activities listed above could equally well be listed as examples of intergroup concern with play. Other examples of play provisions as factors in the intergroup program of constructive hygiene are community social houses, picnic grounds, and automobile camps. A number of states have authorized their communities to establish and maintain play and recreational facilities at public expense.

Intergroup rest.—Legal regulations restricting the work-day to eight hours and less are recognitions of the importance of rest in terms of recreation, relaxation, diversion, and play. The Saturday half-holiday, the summer omission of work on one day in the week in addition to Sunday, and the almost universal business and governmental provision for annual vacation periods are samples of intergroup applications of rest for the constructive physical and mental benefit of the individual and the group. There are also specific laws relative to the hours of labor of women and minors that apply the requirements of rest. There are laws and ordinances in all communities calculated to safeguard the night from disturbing noise so that the hours of sleep may not be interrupted.

PART II. PRINCIPLES OF DEFENSIVE HYGIENE

CHAPTER XX

THE BEGINNINGS AND THE SCOPE OF DEFENSIVE HYGIENE

Defensive hygiene re-defined.—The relations of cause and effect that protect and defend human health and life and prevent disease constitute defensive hygiene. These relations are partly beyond our control and belong, therefore, to what we are describing in this text as autonomic hygiene. They are also partly controllable and belong, therefore, to voluntaristic hygiene.

The beginnings of autonomic defensive hygiene reside in the defensive hygiene of the one-celled organism—the one-celled plant and the one-celled animal. The defensive hygiene of the tissue cell is the basis of the autonomic defensive hygiene of the multicellular individual. It is a composite of defensive, physical-chemical, physiological reactions; internal secretions; tropisms; mechanistic nerve reflexes; instinct behaviors (conditioned reflexes, behaviorisms, "gestalt" reactions) ; and all the other forced chemical, physical, organic, and functional behaviors that more or less successfully protect life and health and prevent disease.

Voluntaristic defensive hygiene appears with the beginnings of intelligent mind. It may be well hidden by the forced behaviors of autonomic hygiene or by the dominance of uncritical belief (health mores and superstition). It may be empirical or it may be scientific. The acquirement of factual knowledge of the causes of health injury and of death, and of ways and means of protecting and defending health and life, preventing disease and postponing death, has given mankind in the slow process of many centuries a powerful scientific defensive voluntaristic hygiene.

Analysis of the causes of health injury.—The facts that furnish scientific proof of the existence of agents, conditions, and influences that injure health and the facts that identify those causes of health injury and describe their natural history (i.e., their nature, sources, occurrence, modes of action, and characteristic effects upon human health and human life and their control) are, as we noted above, largely recent additions to the resources of society for the defense of health. Thousands of years of preceding ignorance and misinterpretation were associated with a well-nigh universal dependence on magic, superstition, tradition, unquestioning custom, or blind habit that for all these ages made

scientific thinking and discriminating judgment difficult or impossible in matters of health.

The modern extension of scientific research into the field of health and disease, particularly within the last seventy-five years, has added a mass of factual evidence to the sum total of dependable human knowledge that makes blind belief in the control of health by spirits or the gods no longer possible to the informed, intelligent mind. Such a mind cannot accept the health advice of the astrologer, the crystal reader, or the fortune teller. It refuses the unscientific, untrained, or illiterate practitioner. Informed intelligence today cannot be so easily duped by unsubstantiated folklore hygiene, or by unprepared, unscrupulous quacks, honest but incompetent healers, cultists, or by fanatics. Superstition is slowly giving way to science. The same power that has given us steam and electricity, the X-ray, radium, the telephone, the telegraph, the radio, the auto, the submarine, and the airplane, the phonograph, and the typewriter is giving us scientific hygiene. Jinx and hoodoos are growing less popular. Information is replacing ignorance. We have a steadily increasing practical knowledge of agents and influences that injure health which makes it more commonly possible to formulate rational judgments for the defense of health than has ever before been true. Because of the improvements that have been made in the defenses of human health the life expectancy of men and women in the enlightened nations of the world today is more than double that of the backward nations that are dominated by ignorance, taboos, and superstitions.

But we have a great uninformed population in all parts of the world that lags behind in the acquisition of information necessary for the formulation of intelligent, discriminating judgments in matters of health. The proved facts of cause and effect in hygiene are not yet such common property as to be a part of the traditions or beliefs of illiterates or near-illiterates. Even our most highly educated citizens are frequently ignorant of the physical, chemical, and biological sciences and are therefore unacquainted with the changeless sequences of hygiene—the inevitable effects of specific causes and the favoring effects of contributing causes that produce, injure, or defend health. Consequently, both the masses and their leaders are too frequently imperfectly or poorly informed, and the health of the individual, the home, and the public con-

tinues to be wasted and lost. There is even now too much that we do not know about health and disease. But the knowledge that science has already given which makes health improvement and disease prevention possible is not generally used. A scientific application of available knowledge by society as a whole, incomplete as that knowledge is, would very largely reduce all and perhaps wholly eradicate some of the avoidable and preventable diseases.

The scientific information we now have makes it clear that the agents and influences that injure health are subject to the same general classification whether we deal with the health of plants or of animals, or with "simple" one-celled living forms, or with the many-celled higher plant, animal, or human organisms. Injury to health or destruction of life may come to the one-celled organism if it suffers structural or functional damage from any cause. These causes are found in the heredity of the organism and in the structural and functional experiences of the organism. Injury comes to the more highly developed forms of animal and plant life from the same sources. Health injury may be due to the quality and assortment of the chromosomes with which the fertilized ovum or the pollenized ovule has been supplied, and health injury may be consequent on the structural or functional experiences of the developing, growing seed or plant or on the structural and functional experiences of the developing fertilized ovum, foetus, infant, child or youth, or of the developed adult. Heredity may supply a health handicap at the beginning of a life; or environment may bring experiences that cause health damage during life.

The heritage of the one-celled plant or more primitive one-celled animal is largely if not wholly asexual. There is but one parent cell. It follows that inherited health possibilities in these forms of life are limited to those furnished by the simple division of single parent cells. This heritage has been derived in an unbroken continuity of parent-cell divisions from Cambrian and pre-Cambrian single-cell ancestors some hundreds of millions of years ago, unless conjugation of one-celled forms at appropriate intervals is requisite for continuity. The heritage of the many-celled and many-organed human is bisexual. The two human parents furnish a heritage of chromosomes, each from his or her germinal substance, that have an inherited organization of great complexity made up from transmissions of preceding combinations of chromosomes in egg and sperm that have been contributed by generation after

generation of human and pre-human ancestral lives that "date back" many thousands, probably many millions, of years.

The structural and functional experiences of the one-celled organism are limited to the events of a simple one-celled life, spent in a restricted one-cell environment, for example, the amoeba living in a drop of slime. The events in a one-celled life are associated with respiration, nutrition, excretion, reproduction, and response to external stimuli, such as change of temperature, light, and pressure. Respiration, nutrition, excretion, reproduction, and response to stimulation are largely functional events in the life of the one-celled organism, even as they are in the many-celled organism. The structural experiences of the one-celled organism are events in which inanimate, injurious, mechanical, physical, or chemical influences may be brought to bear upon the architecture of the organism; or living enemies may become causes of such damage.

The structural and functional experiences of the higher forms of life are correspondingly more varied and complicated. But they are nevertheless subject to the same general classification. The experiences of the higher forms that are more largely functional experiences are associated with such phenomena as nutrition (including excretion), respiration, and reproduction; or with reception of stimuli and motor, secretory, psychic, or other responses to stimulation. We are calling these "functional" experiences, but they are all also structural experiences; that is to say, they are organic as well as functional.

We would not be so much concerned with the health affairs of an amoeba or a bacterium, a shrub or an insect, a tree or a guinea pig, if the agents that injure their health and the agents that injure human health were not so generally the same.

But the human being is different from all other living things in the possession of an educable, intelligent mind, that gives a capacity to remember, to learn, to think, to reason, and to form discriminating judgments. This educable human intelligence has made the world small. Mankind is no longer limited in experience to the home environment like the amoeba, the tree, the forest animal, or the primitive human. The functional and structural experience of the individual is now more or less world wide and is subject to direct and indirect relations with all his fellow-kind.

Men and women of today are, therefore, not only subject to the possible inheritance of a variety of health injuries transmitted

to them by their diverging lines of contributing ancestors in excess of all other forms of life, but they are in addition subject to a more varied and more complicated functional and structural experience than any other form of life, or than has ever come to the human race before. These experiences bring a greater opportunity for the acquirement of health injury than ever before. Were it not true that science and education have with more than equally rapid advance given rational methods of voluntaristic defensive hygiene, the human race would be destroyed by the agents that injure health even as were those prehistoric forms of animal life that once so abundantly inhabited the earth.

Intelligent observation and patient, painstaking research, contributed by critical minds in all parts of the world, among all sorts of people, and for a very long time, have assembled the scientific knowledge that constitutes our information today concerning defensive hygiene. Some of this information was inscribed on the cuneiform bricks of Babylonia or written in hieroglyphics on the walls of Egyptian tombs 4,000 years ago and was recorded by Hippocrates, 2,300 years ago. But, as we have said, the mass of our scientific defensive hygiene has been contributed within the past seventy-five years or less by students of biology, physiology, anatomy, pathology, psychology, and medicine. It is confidently believed that the great mass of scientific health information that has been accumulated is but a small fraction of the contributions that will be made in the future. The main and important subjects of defensive hygiene will be discussed in the succeeding pages of this text as follows:

The Defensive Hygiene of Heredity: The protection and defense of good heredity through the protection and defense of desirable, non-pathogenic genes, and the prevention of bad heredity through the eradication and control of pathogenic genes.

The Defensive Hygiene of Heritage: The protection and defense of good heritage through (1) the prevention of deprivations and deficiencies of necessities for adequate nutrition, excretion, organic and functional activity, and rest; (2) the prevention of injury from mechanical, physical, and chemical agents; (3) the eradication, isolation, and control of pathogenic organisms (pathogenic bacteria, protozoa, and metazoa); and (4) the control of unfavorable physical-chemical, biological, and social environments that contribute to the production of poor health, disease, and death.

CHAPTER XXI

HEREDITY: THE DEFENSIVE HYGIENE OF HEREDITY

Definition of disease.—In this text the word "disease" is used with a very broad meaning. Any deviation from the normal, whether it be a deviation of anatomy (i.e., structure), physiology (i.e., function), or of social behavior, that does not benefit the individual is classified here as a somatic (bodily), a mental, or a social disease. All three sorts of deviation may be obvious in a single disease; no disease is ever exclusively structural, functional, or social.

From this point of view a disease may be serious or inconsequential. Thus, along with the diseases that ruin the mind, cripple the body, or destroy life, we recognize as diseases many simple abnormal or unusual conditions that may be of little or no disadvantage to the individual. A thumb and five fingers or an extra lumbar vertebra are anatomical abnormalities that may or may not be of disadvantage to the individual who inherits them.

Definition of hereditary disease.—A hereditary disease is a disease that is caused by self-perpetuating factors (genes) that are contained in the chromosomes of the germ-cells. These factors are transmitted from generation to generation through reproductive matings with or between carriers of such germ-cells. The diseases they cause reappear in, or skip, succeeding generations in mathematical accord with the Mendelian laws of recession and dominance.

History of our knowledge of hereditary disease.—Recognition of the hereditary transmission of disease from generation to generation is very old. Such recognition is recorded in the Hippocratic writings and in those of Socrates, Plato, and Plutarch, in the writings of Lycurgus of Sparta and Aristotle, as well as in the Old Testament. Plato's reference to the breeding of cattle, Lycurgus' observation that children of a bad breed prove their bad qualities, and Aristotle's discussion of the causation of sex and his curiosity over the fact that, in a certain union between a white mother and a negro father, the children were white and the grandchildren colored are ancient records that must have been preceded by a much more ancient belief in heredity and in the inheritance of disease.

Common beliefs in the regularity of the behaviors of the spirits (or ghosts) of ancestors exhibited in what we describe today as hereditary diseases are found in the traditions of primitive and illiterate people of ancient as well as modern times. One is thus encouraged to the conclusion that the origins of our knowledge of heredity and hereditary disease are prehistoric, arising probably long before any of the races of men had learned the art of writing.

But, while our empirical knowledge of heredity and hereditary disease is very old, our scientific knowledge of heredity and hereditary diseases, their causes, carriers, and dissemination, is very young. The statistical researches of Galton (1865) were of great importance in the proof they furnished that exceptional mental capacities are inherited, but it was not until Gregor Johann Mendel's researches in plant hybridization, published but unnoticed in 1865, were discovered and given prominence by De Vries in 1899 that the scientific experimental method of investigating heredity was established. Finally, the accumulated researches in the field of cytology in the last seventy-five years have furnished a mass of scientific knowledge of the physiology of heredity that along with the products of the experimental methods of Mendel and others has furnished mankind with methods of research and with a body of information that places our knowledge of heredity and of hereditary disease on a solid scientific basis.

The causes and carriers of hereditary diseases.—Thus our scientific knowledge of the causes, carriers, and dissemination of hereditary diseases is furnished by cytology and experimental genetics. Cytological research (the study of the cell) has furnished facts that describe the physiology of the germ-cell and prove that the chromosome is the container of factors that determine heredity (the genes) and that the germ-cell (gamete) is the carrier of those factors. Thus, the chromosome is the container of the gene or genes that determine hereditary disease, and the paternal germ-cell (the sperm) and the maternal germ-cell (the ovum) are carriers of disease-determining genes. The extent to which the cytoplasm or other constitutents of the germ-cell may determine or influence heredity has not been discovered. It is believed that the cytoplasm plays an indispensable though secondary part in the physiology of heredity and, therefore, in hereditary disease.

Experimental researches in the heredity of plants and animals

(experimental genetics) have supplied ample evidence in proof of the validity of the Mendelian conceptions of dominant and recessive genes and of the segregation and independent assortment of genes that form the basis of the laws of heredity as we know them today. The reader is referred to the chapter on heredity in our discussion of constructive hygiene for a statement of the physiology of the chromosomes and for a discussion of the laws of heredity. One cannot understand the causes, carriers, and distribution of hereditary disease or the defensive hygiene of heredity unless he understands the main facts of the physiology of the germ-cell and the main principles on which are based the laws of heredity. It is, however, not necessary for this purpose to memorize the details of that fascinating story.

We have seen that the experimental genetics of Gregor Johann Mendel reveal certain orderly unvarying sequences of cause and effect in the inheritance of garden peas. Later investigations of the heredities of all forms of plant and animal life confirm his findings. Apparent contradictions have proven on further research not to be contradictions.[1] With the further advances of knowledge secured from experimental genetics and from cytological and embryological research, the conviction grows that there are no phenomena of heredity that are inconsistent with the facts demonstrated by Mendel.

The great mass of scientific evidence to which we have made frequent references demonstrates that the physiological organization of the germ-cell supplies the mechanisms and orderly procedures that carry out the sequences of cause and effect that constitute the laws of Mendel. The phenomena of dominant and recessive unit-characters that are covered by the Mendelian conception of the gene are exhibited in response to the orderly behaviors of the contents of the nucleus of the germ-cell. The word "gene" is used to describe our conception of the chemical something within the chromosome of the germ-cell that accounts for the phenomena of dominance and recession. This chemical something is a constituent of the chromomere or of its ultramicroscopic component granules.

The precision of the mechanisms of cell-division in meiosis, fertilization, and mitosis account for Mendel's laws of segregation

[1] Edwin Grant Conklin, *Heredity and Environment in the Development of Man* (Princeton University Press, 1929), p. 100.

and independent assortment of the factors that determine heredity. The behavior of the chromosomes in the different stages of the chromosome cycle accounts for the details of the segregation and assortment of paternal and maternal genes.

The inheritance of certain diseases is becoming increasingly predictable because of our growing knowledge of the behavior of the germ-cell as a whole and of the chromosomes in particular. The genetic continuity of the chromosomes and of the genes they carry, the linkage of genes, their linear order in the spireme, the "crossing-over" phenomena of the genes while the chromosomes or spiremes are conjugating, and their segregation, assortment, and distribution with the chromosomes are products of physiological mechanisms of precision that are concerned with the fulfillment of the unalterable relations of cause and effect in heredity.

The chromosomes of man carry hereditary units that are pure dominants, pure recessives, or combinations of dominants and recessives. Mankind is a single species. There are, however, many distinct races of men. Within each race, the chromosome content is evidently largely a mixture of alternative dominants and recessives that are common to the race. The chromosomes may carry hereditary units that, in their composite influence working with the germ-cell of which they are inseparable parts, act as dominants for cell vigor, tissue growth, organic development, functional integration of the endocrine and other organs, somatic strength, immunity, mental and nervous stability, and all other composite heredities that constitute vigorous, enduring health. Homologous chromosomes may carry recessives for opposite or alternate characters.

The chromosomes may carry dominants for certain disease characters and alternative recessives for contrasting normal health characters or the chromosomes may contain an indifferent assortment of alternate genes that are neither dynamically constructive nor destructive as dominants or recessives in relation to health or disease. But whatever the assortment of dominants and recessives furnished by the union of two haploid (half or single) groups of chromosomes in fertilization, the resulting diploid (double) group will develop under a favorable environment in accord with the laws of dominance and recession demonstrated by Mendel. The action of these laws is more complicated in man than in Mendel's garden plants. There is a far greater number of factors involved. The influence of environment and experience is more varied and

puzzling. Nevertheless, subject to these very obvious complexities, the hereditary sequences of cause and effect in man are the same as in other forms of life.

The pathogenic genes.—The hypothetical elementary entity or factor that is essential to or determines the development of a particular hereditary disease character may be designated as a "pathogenic gene." It is probable that all our inherited diseases are products of groups of genes that determine them rather than of single genes. Nevertheless, the single gene must be regarded as the elementary hypothetical something in which resides the determining or differentiating influence upon which the orderly sequences of cause and effect in heredity depend.

The haploid group of twenty-four chromosomes that is characteristic of the germ-cell of the human species contains a linear series of genes in orderly sequence that are almost the same in every haploid group in every individual of the two thousand million living individuals of the human species. If the chromosomes of the haploid groups were lettered, A, B, C, D, and so on so that every one of the twenty-four in each group had a designatory letter, every A-chromosome in any haploid group would be almost the same as every other A-chromosome in every other haploid group. All the chromosomes with the same letters (i.e., all homologous chromosomes) would be functionally the same. But no chromosome of one letter would be like any chromosome of any other letter. That is to say, all chromosomes that are not homologous would differ from each other. Their resemblances and differences are due to resemblances and differences in their constituent genes. The genes of a single chromosome are very like the genes of every homologous chromosome and very different from all others.

The similarities of the homologous chromosomes and their contents produce the characteristics of the race. The dissimilarities of the genes of homologous chromosomes produce hereditary dissimilarities in family lines within the race. These dissimilarities are determined or differentiated by groups of genes or associations of genes that maintain their group relationship from one generation to another. This grouping is a linkage of genes in series within the chromosome and is not destroyed by meiosis or mitosis.[1]

[1] This linkage may be disturbed by the phenomenon of crossing over during the stage of conjugation of the spiremes described by Morgan and others.

Morgan has proved the existence of recessive genes in Drosophila that in the absence of the alternative dominant genes are fatal. He has named these "lethal genes." We have no information concerning lethal genes in human chromosomes. But we have convincing evidence of the existence of genes that produce a number of more or less well-known human diseases, some of which are serious. These genes may properly be designated as "pathogenic genes." Like all other genes, certain of the pathogenic genes are dominants, others are recessives.

We are forced to the conclusion that pathogenic genes or pathogenic gene-linkages are carried in certain chromosomes in certain families of the human race, and that in some cases at least these hypothetical Mendelian units are as specific for disease and as dangerous to human health and life as are the living organisms that cause tuberculosis, syphilis, and other well-known specific and serious diseases of man, and we must recognize the fact that a particular gene or a series of particular genes linked together is the determining cause of a heritable disease; the chromosome and the germ-cell are the containers of such genes; and the adult individual is the carrier and disseminator. The protection of the individual, of future children, and of society in general from known heritable diseases may be achieved in whole or in part only with the aid of a scientific knowledge of the causes, carriers, and disseminators of hereditary diseases.

The carriers and disseminators of pathogenic genes.—Obviously, the individual who has a hereditary disease is a carrier and may be a disseminator of the genes of the disease that he has inherited. He is the product of a union of two haploid groups of originating chromosomes. Either the paternal group or the maternal group, or both originating groups, of chromosomes must have contained the specific genes that cause his heritage of disease. Hereditary disease can be transmitted in no other way. The repeated divisions of those pathogenic genes in the successive cleavages of the originating fertilized ovum must have perpetuated those genes in the reproductions of the paternal or maternal chromosome group or both groups for the chromosome equipment of every one of the thousands of billions of tissue cells that form his body, supply its energies and functions, and, with the help of equally important environmental experiences, give it growth, development, individuality, personality, and character.

Thus, the pathogenic genes contained in either the paternal or maternal chromosome group, or in both groups that participate in a fertilization, may influence every somatic cell and every germ-line cell produced by the subsequent multitudinous cleavages of that fertilized ovum in the making of a man.

Thus every individual who has a hereditary disease carries the genes of that disease in one or both his parental groups of chromosomes in all his somatic cells and in all his germ-line cells. The dynamic influence of those special genes in his somatic cells is a part of the total composite integrating dynamic developmental influence of all his chromosomes, cells, tissues, and organs, working together with the help or hindrance of the stimulating developmental influences of their experiences with their internal and external environments. The resultant of all these forces of heredity and environment makes of him an individual more or less perfectly finished, equipped, and operative in the purposes of human life. The specific differential effects of the genes of the hereditary disease which he carries may be obvious early in the structure and function of certain of his somatic cells, or these pathological effects may not be evident structurally at any time. The functional evidence of his hereditary disease may not appear before adolescence or even full maturity. But whatever the nature of the hereditary disease and regardless of its early or late appearance, the factors that determine its character and exhibition in the individual are contained in the nuclei and possibly the cytoplasm of his somatic cells, and were inherited by those somatic cells from the nucleus and possibly the cytoplasm of the fertilized ovum whence they came.

An individual with a hereditary disease must carry the genes of that disease in one or the other or both chromosome groups in all his diploid germ-cells. We have convincing and compelling evidence of this fact. We know of no other condition under which the transmission of hereditary disease from parents to offspring could take place. The individual is thus the carrier of the genes of his hereditary disease and he is potentially their disseminator through fertilization to the somatic cells and germ-line cells of the children for whose existence he and his mate may be responsible.

We have seen that every mature plant and animal is a carrier of germ-cells. Under normal conditions of marriage and mating every adult human may be physiologically an assorter and dis-

tributor of genes for the construction of new individuals and the making of new personalities. The individual who has inherited maternal and paternal genes that are dynamic influences toward health will contribute qualitatively equivalent fractions of those same health-producing genes to the somatic cells and germ-line cells of his children. The individual who has inherited maternal or paternal genes that are dynamic influences toward disease will contribute qualitatively equivalent fractions of those same pathogenic genes to the somatic cells and germ-line cells of his children.

An individual who exhibits an inherited disease character is a carrier of germ-cells that contain the genes that produce that disease character. These pathogenic genes may have had one or another of the following derivations: from a pathogenic gene (or genes) contained in the maternal haploid chromosome group (in the ovum), or in the paternal haploid chromosome group (in the sperm), or they may have been derived from genes of the same hereditary disease carried in both the germ-cells that participated in the fertilization that gave him his heritage.

Probability of transmitting hereditary disease.—Because of our knowledge of the physiology of the germ-cells acquired through experimental genetics and cytological research, we are aware of certain unvarying relations of cause and effect in heredity that are generally stated as the "laws of heredity." A knowledge of these laws and the details on which they are based enables the experienced student of genetics under certain conditions to predict disease heritages with mathematical precision. The conditions under which the transmission of hereditary disease from parents to children may be predicted are listed below. This information is of basic importance but it is not expected that the lay student will attempt to retain a memory of the details. These conditions are discussed here, as has been the case with technical discussions elsewhere in this series, in order to emphasize the very important fact that the laws of hygiene are based on a vast amount of painstaking scientific research. It is not necessary that the lay reader should become a student of genetics (or eugenics), but it is of very great importance that he should know the nature of the scientific information available in the field of heredity and that dependable advice for the solution of his personal, family, or community problems of heredity should come from dependable scientific authority and not from community tradition, neighborhood

gossip, superficially educated healers, or even from his own unaided efforts to interpret the meaning of texts such as this one.

Intermarriage between families with no known history of hereditary disease is not likely to result in the appearance of hereditary disease in the children produced. Nevertheless, there is always the possibility that the genes of the same recessive disease may be hidden in the germ-cells of both families. As a rule we have no means of knowing with certainty that recessive genes are absent or present. In the event that both parents are carriers of the recessive genes of the same disease the chance assortment of many sperms and many ova would bring maternal recessives and paternal recessives together in one fertilization out of every four and would cause the inheritance of the recessive disease by one child out of every four children born. Two of the other children in each group of four would be carriers of the genes of the recessive disease.

Intermarriage between apparently normal individuals, one mate coming from a family with no known history of hereditary disease and the other coming from a family with a history of hereditary disease, involves a slightly increased risk that some of the children of such a union may inherit the disease. If the one mate comes from a family with a history of a recessive hereditary disease, the probability that he is a carrier of the genes of that disease depends upon which generation of his ancestors exhibited the disease. If one of his parents had the disease, he would carry the genes of that recessive in at least one half his haploid germ-cells. If the ancestral history of the disease were more remote, the probability of his chromosomes containing the genes of the disease would decrease in geometric proportion.

If the mate coming from a family with no history of this same hereditary disease should nevertheless be a carrier of the recessive genes of that disease, the chances that the children of the union would exhibit the disease would be increased. The extent of the risk would depend upon the chance fertilizing union of maternal and paternal genes for the same recessive disease.

Intermarriage between apparently normal individuals, each coming from a family in which there is a present or past history of recessive hereditary disease, involves a risk. If in the family of each mate the disease is exhibited by one parent and by one or more brothers or sisters of the mate, both mates would be car-

riers of the genes of the recessive disease and by the law of chance would transmit the disease to one child out of every four and transmit the genes of the recessive disease and its dominant alternate normal character to two of the remaining three in each group of four children.

If the history of the recessive disease included brothers or sisters in each family but not the parents in those families, the probability that each normal mate would be a carrier of the genes of the recessive heredity would be twice as great as the probability that they would be carriers of pure dominants for the alternate normal character. One child out of every four from such a marriage would exhibit the recessive disease, two would be carriers of recessives, and one would be a carrier of pure contrasting health dominants.

If the past history of the two families contained records of such recessive hereditary disease, the chances that the mates would be carriers would be reduced in geometric proportion to the remoteness of the ancestry, and the chances that their children would exhibit the disease or be carriers of the genes of the disease would be correspondingly small.

Intermarriage between absolutely normal individuals, both belonging to families with a present or past history of dominant hereditary disease, involves no health hazard for their offspring. The problem in such a situation is to make sure that each of the contracting parties is in reality free from the dominant heredity. It often happens that such heredities do not display themselves until later in life.

Intermarriage between an individual with a dominant hereditary disease and one who is free from such a disease involves a health risk for the children of such a union. If the mate with the disease is a carrier of dominants from both his parents, all the children will exhibit the disease and all will be carriers of genes of the dominant disease and genes of the alternate normal recessive. If the mate with the dominant disease has inherited the disease from but one of his parents, two out of every four of the children of the union will be likely to exhibit the disease.

Marriage between individuals both of whom have the same hereditary disease involves a very serious health hazard for their children. If each is a carrier of pure dominant pathogenic genes, all the children will inherit the disease and all will be carriers of

pure dominants. If each is a carrier of dominant pathogenic genes and recessive genes for the contrasting normal, three out of each group of four children will be likely to exhibit the disease and will of course be carriers and potential distributors of the genes of the disease. Two of every four would carry only pure dominant genes of the hereditary disease. One child out of four would not exhibit the disease nor would he be the carrier of the genes of the disease. With the hereditary diseases that are classed as dominants, the disease is always exhibited if the genes of the disease are present. If the disease is not exhibited, there are no genes of the disease carried in the chromosomes of the individual concerned.

If the diploid germ-cells of either of these mates with dominant hereditary disease contain no genes of the recessive alternate normal character, all the haploid germ-cells produced by such diploid germ-cells will contain genes of the dominant disease character. In that event the marriage between these two hypothetical individuals would result in the appearance of the dominant hereditary disease in all their children.

CHAPTER XXII

MORE ABOUT THE DEFENSIVE HYGIENE OF HEREDITY

The possibility of an acquired health injury becoming heritable.—In order that a man or a woman may transmit the cause of health injury which he has acquired (i.e., which he has not himself inherited), he must introduce a living self-perpetuating factor (a new gene or group of genes) into a germ-cell chromosome that will successfully take part in the processes of fertilization. Obviously, such an event could not occur.

Or the individual, to be the transmitter of an acquired disease-character, must in some manner alter the structure of at least one of his germ-cell chromosomes so that the completeness of one or more of the factors (genes) in that chromosome is damaged or changed. And these alterations must become perpetual, recurring in each longitudinal division of that chromosome and of all the germ-cell chromosomes produced by its descendant chromosomes.

It is impossible in the present stage of our scientific information to conceive of the introduction of genes by any other method than fertilization.

It is possible that circulating poisons in the capillary blood surrounding the gonad glands of the testes or of the ovaries may damage or alter the gonad cells and thus alter one or more of the chromosomes therein; or damage the chromosomes of individual germ-cells and thus lead to the production of damaged offspring. The poisons of syphilis seem to have such an effect. People sick with lead poisoning appear to have damaged offspring for this reason. Alcohol circulating in the blood is thought to be responsible for such damages. These effects of lead and alcohol have not been proved.

But it is obvious that no communicable disease of germ origin can be inherited. There is no conceivable way in which a living disease parasite could become a gonad-cell-cytoplasm resident, or a gonad-cell-chromosome resident, or a germ-cell-cytoplasm resident, or a germ-cell-chromosome resident, and then become a living cytoplasm or chromosome factor reproducing itself generation after generation in an integrating harmony with the well-known biological events of the cell in development and inheritance.

If there is such a thing as the inheritance of acquired disease,

it is the inheritance of the influence of damages done the germ-cell by the disease and not an inheritance of the disease itself.

And it is even more obvious that the mechanisms of heredity as we now know them will not admit of the possibility of inheriting an acquired bodily mutilation. The children of a one-legged parent have two legs.

For the same reason it is obvious that there can be no such thing as the inheritance of maternal impressions during the prenatal period.

Heredity as a source of structural and functional defects.—Painstaking observations made by a great many patient investigators working independently in all the fields of animal and plant life establish the fact that certain health injuries are products of heredity and may be noted generation after generation in the family lines affected. These injuries are often heritages of structural defects that are obvious. Others are hereditary structural defects that are revealed only on microscopic examination. There is in addition a large and very important group of hereditary health injuries that show themselves as functional diseases with, as yet, no structural explanation.

Structural heredities that injure health.—A great many thousands of observations made by a very large number of tireless men and women trained as scientific investigators working in the one-celled plants and animals, and on the many-celled plants and animals, and on humans, unite to prove that structural heritages that deviate from the normal are common and that functional heritages of abnormal qualities for which there are at present no known structural bases are also common. It is probably true that every organ and every tissue of the human body exhibits hereditary differences from the "normal" or usual structural heritage of organs and tissues exhibited by the "average" individual of the family or race involved. A few of these inherited structural deviations are responsible for functional deviations from the normal that are obviously incapacitating and incompatible with good health. In many of these abnormal structural heritages the damage to functional capacity or efficiency is less evident or absent.

Small stature or dwarfism is a recorded heredity in some families. A thumb and five fingers, and a big toe and five smaller toes appear on the hands and feet of members of certain families in succeeding generations. The inherited "lobster claw" is a di-

vided or split hand with one "finger" on each side. The same structural heritage appears in the feet of some members of the families in which this heredity occurs. A number of other structural heritages exhibited by the hands and the feet have been recorded.

Heritages are recorded of excess of hair distributed generally over the body; absence of hair; absence of pigmentation of the skin; scaly, horny skin; absence of teeth; supernumerary teeth; absence of finger nails; and supernumerary mammae.

A number of structural heritages with consequent functional deviations are recorded for the eyes.

1. Clinical records show that at least thirty-four defects of the eye, including the lids and muscles, have been found to be distinctly hereditary. Of these, at least eight are apt to produce practical blindness—either directly or indirectly. The principal defects in this group are corneal degeneration, persistent pupillary membrane, certain forms of cataract, glaucoma, retinitis pigmentosa, macular degeneration, optic atrophy, retrobulbar neuritis, blindness with idiocy, buphthalmos, and microphthalmia.

2. In our report in 1921, reasons were given for estimating that we have now in the United States from about 5,000 to 7,500 blind from hereditary defects, and that their cost probably exceeds $2,000,000 annually. The number is certainly not decreasing, and thus far no special attempt has been made to limit their continued propagation.[1]

The bony skeleton exhibits hereditary characteristics that may be identified sometimes by use of the X-ray. The heritages shown by the hands and feet noted above are usually of bony structure. One family is recorded as carrying a heredity of but one patella (knee-pan). Cleft palate and harelip are reported to be hereditary.

Our recent and growing knowledge of the endocrine glands (the ductless glands or the glands of internal secretion) is accompanied by convincing evidence that these glands exhibit structural heritages with consequent functional deficiencies in some families. The structural deviations may not be apparent. We judge their presence by the characteristic functional abnormalities of those heredities. In the present stage of our knowledge two of the endocrine glands, the thyroid gland and the Islands of Langerhan's in the pancreas, give the best example of structural endocrine-gland heredities. An enlarged thyroid gland is called a goiter. Some, but not all, kinds of goiters are due to heredity. The inherited

[1] "Report of Committee on Hereditary Blindness," *Journal of the American Medical Association,* July 26, 1924, p. 270.

thyroid diseases are serious. Diabetes is a common disease that in a number of cases, possibly in all cases, is due to hereditary structural disturbances of the Islands of Langerhan's in the pancreas.

Incidentally, it may be remarked that our scientific knowledge of these two glands and their secretions has given to modern medicine a remarkable control over the diseases that result from a deficiency or deprivation of secretions from either of them.

Structural heritages of the brain, spinal cord, and peripheral nerves are among the more serious sources of health injury. The abnormal mental and nervous functions displayed by the idiot and the imbecile are due to structural brain heritages.

Heritages of functional defects for which no structural heritages have as yet been identified.—The most important of these functional inheritances are evident in certain mental and nervous disturbances. These heritages are of very great importance. They are responsible for a large proportion of feeble-mindedness, "insanities," and other psychoneuroses.[1]

A very curious inherited health injury that is neither mental nor nervous and has no known structural basis is evident in a disease known as "hemophilia." People who inherit this disease are called "bleeders," or "hemophiliacs." A hemophiliac has much difficulty in stopping the flow of blood following the slightest trauma that breaks into his blood circulation. A mere scratch may bleed for hours or even days and a considerable wound easily becomes fatal. This disease is due to a heritage in which there is an absence of the chemical bodies, or of one of the chemical bodies, that cause the blood to clot. We do not know what glands of the body manufacture these chemicals.

Hemophilia is a sex-linked heredity. As a rule only male children are bleeders. The disease is transmitted through the mother, exhibited ordinarily only by the sons and transmitted only by the daughters. The genealogy of certain hemophiliacs has been traced back for more than two hundred years.

There are functional heritages with no known structural causes exhibited by each of the physiological systems of the body.

[1] A psychoneurosis is a combination of mental disease and nerve disease, more of a nervous disease than a mental disease. A mental disease is a psychosis. A nerve disease, especially a functional nervous disease or one which is dependent on no evident lesion, is a neurosis.

Thus we find abnormal digestive heritages, respiratory, circulatory, excretory, and reproductive heritages, as well as abnormal mental heritages. The immunity phenomena of the blood and tissue fluids in certain families show characteristic hereditary deviations for which there is no structural explanation.

The fact that we are commonly unable to see an organic basis for an inherited health injury even with the aid of the microscope is not a matter of great importance in the field of hygiene. Such bases of heritable disease may exist in ultramicroscopic structures. They may be results of ultramicroscopic chemical and physical relations present in living tissue cells. Furthermore, the structure and structural relations of the molecules and atoms and electrons of the living cell are probably altered as soon as the cells die. These structures—that is, these organic bases of heritable health injuries—are then under the conditions of laboratory analysis, even farther beyond the reach of our relatively crude methods of chemical and physical analysis, not only because of their microscopic or ultramicroscopic size, but also because of the fact that they are dead or dying.

But the fact that the structural basis of heredity, and therefore of heritable disease, is known to be located in the self-perpetuating chromosomes of the germ-line cells and of the germ-cell is of the very greatest importance. And the facts that we have reported concerning the chromosome mechanisms that carry out the Mendelian laws and govern whatever other laws of heredity we have or may have are essential to an understanding of the inheritance of disease.

The diseases of dominant and recessive heredities.—The diseases of heredity have been classified on preceding pages as either structural heritages or functional heritages. This classification is useful for descriptive purposes in the interest of better understanding. But a more important classification for the purposes of defensive hygiene recognizes hereditary diseases as products of dominant genes or recessive genes. Dominant pathogenic genes cause heritages of dominant disease characters that appear in all the offspring. Recessive pathogenic genes cause heritages of recessive disease characters that appear only in those fertilizations in which there is no normal contrasting dominant gene. The probabilities of transmitting a heritage of recessive disease characters are discussed above as well as on certain later

pages. The point to be emphasized here is that, with the advance of our knowledge of hereditary diseases, we find them classifiable in the following general groups: (1) those that are caused by dominant pathogenic genes; and (2) those that are caused by recessive pathogenic genes.

The conception of dominant and recessive pathogenic genes is based on the researches and conclusions of Mendel, to whose work so many references are necessarily made in this text. The following quotation from Conklin[1] presents a list of normal characters and disease characters ("teratological and pathological characters") that are known to be heritable. It will be noted that these lists are in two columns, one being a column listing dominant characters, and the other a column listing recessive characters. Conklin's list of dominant and recessive "teratological and pathological characters" is a classification of what we are regarding here as dominant and recessive diseases caused by dominant or recessive pathogenic genes.

Mendelian inheritance in man.—The study of inheritance in man must always be less satisfactory and the results less secure than in the case of lower animals and for the following reasons: In the first place there are no "pure lines" but the most complicated intermixture of different lines. In the second place experiments are out of the question and one must rely upon observation and statistics. In the third place man is a slow breeding animal; there have been less than sixty generations of men since the beginning of the Christian era, whereas Jennings gets as many generations of *Paramecium* within two months and Morgan almost as many generations of *Drosophila* within two years. Finally the number of offspring are so few in human families that it is impossible to determine what all the hereditary possibilities of a family may be. Bearing in mind these serious handicaps to an exact study of inheritance it is not surprising that the method of inheritance of many human characters is still uncertain.

Davenport and Plate have catalogued more than sixty human traits which seem to be inherited in Mendelian fashion. About fifty of these represent pathological or teratological conditions, while only a relatively small number are normal characters. This does not signify that the method of inheritance differs in the case of normal and abnormal characters, but rather that abnormal characters are more striking, more easily followed from generation to generation, and consequently statistics are more complete with regard to them than in the case of normal characters. In many cases statistics are not sufficiently complete to determine with

[1] Edwin Grant Conklin, *Heredity and Environment in the Development of Man* (Princeton University Press, 1929), pp. 117 *et seq.*

certainty whether the character in question is dominant or recessive, and it must be understood that in some instances the classification in this respect is tentative. A partial list of these characters is given herewith:

MENDELIAN INHERITANCE IN MAN

Normal Characters

DOMINANT	RECESSIVE
Hair:	
Curly	Straight
Dark	Light to red
Eye Color:	
Brown	Blue
Skin Color:	
Dark	Light
Normal pigmentation	Albinism
Countenance:	
Hapsburg type (thick lower lip and prominent chin)	Normal
Temperament:	
Nervous	Phlegmatic
Intellectual Capacity:	
Average	Very great
Average	Very small to feeble-minded

Teratological and Pathological Characters

DOMINANT	RECESSIVE
General Size:	
Achondroplasy (dwarfs with short, stout limbs but with bodies and heads of normal size)	Normal
Normal size	True dwarfs (with all parts of the body reduced in proportion)
Hands and Feet:	
Brachdydactyly (short fingers and toes)	Normal
Syndactyly (webbed fingers and toes)	Normal
Polydactyly (supernumerary digits)	Normal

DOMINANT	RECESSIVE
Skin:	
Keratosis (thickening of epidermis)	Normal
Epidermolysis (excessive formation of blisters)	Normal
Hypotrichosis (hairlessness associated with lack of teeth)	Normal
Kidneys:	
Diabetes insipidus	Normal
Diabetes mellitus	Normal
Normal	Alkaptonuria (urine dark after oxidation)
Nervous System:	
Normal	Multiple sclerosis (diffuse degeneration of nerve tissue)
Normal	Meniere's disease (dizziness and roaring in ears)
Normal	Chorea (St. Vitus dance)
Normal	Thomsen's disease (lack of muscular tone)
Huntington's chorea	Normal
Eyes:	
Hereditary cataract	Normal
Pigmentary degeneration of retina	Normal
Glaucoma (internal pressure and swelling of eyeball)	Normal
Coloboma (open suture in iris)	Normal
Displaced lens	Normal
Ears:	
Normal	Deaf-mutism
Normal	Otosclerosis (rigidity of tympanum, etc., with hardness of hearing)

Sex-Linked Characters

(Recessive characters, appearing in male when simplex, in female only when duplex)

DOMINANT	RECESSIVE
Normal	Gower's muscular atrophy
Normal	Haemophilia (slow clotting of blood)

DOMINANT	RECESSIVE
Normal	Color blindness (Daltonism; inability to distinguish red from green)
Normal	Night blindness (inability to see by faint light)
Normal	Neuritis optica (progressive atrophy of optic nerve)

Summary.—The principles of heredity established by Mendel are almost as important for biology as the atomic theory of Dalton is for chemistry. By means of these principles particular dissociations and recombinations of characters can be made with almost the same certainty as particular dissociations and recombinations of atoms can be made in chemical reactions. By means of these principles the hereditary constitution of organisms can be analyzed and the real resemblances and differences of various organisms determined. By means of these principles the once mysterious and apparently capricious phenomena of prepotency, atavism, and reversion find a satisfactory explanation.

Before the establishment of Mendel's principles, heredity was, as Balzac said, "a maze in which science loses itself." Much still remains to be discovered about inheritance, but the principles of Mendel have served as an Ariadne thread to guide science through this maze of apparent contradictions and exceptions in which it was formerly lost.

Hereditary feeble-mindedness as an example of recessive inheritance of disease.—Feeble-mindedness is not necessarily hereditary. This mental disease may be the result of other causes than heredity. It may be caused by mechanical, physical, or chemical agencies. It may follow infectious diseases. Thus, feeble-mindedness may be an acquired mental disease. Acquired feeble-mindedness is not transmissible.

But we have a great deal of evidence of the existence of hereditary feeble-mindedness, and this evidence classifies this heritage as a product of recessive factors—that is to say, of pathogenic recessive genes.

All feeble-minded men and women whose feeble-mindedness is due to heredity are carriers of recessive genes of feeble-mindedness in the chromosomes of all their germ-cells. When both parents are hereditarily feeble-minded all their children are feeble-minded and all these children are carriers of the recessive genes for feeble-mindedness in all their germ-cells.

If a person with a heritage of feeble-mindedness mates with a person of normal mind who is not a carrier of the recessive

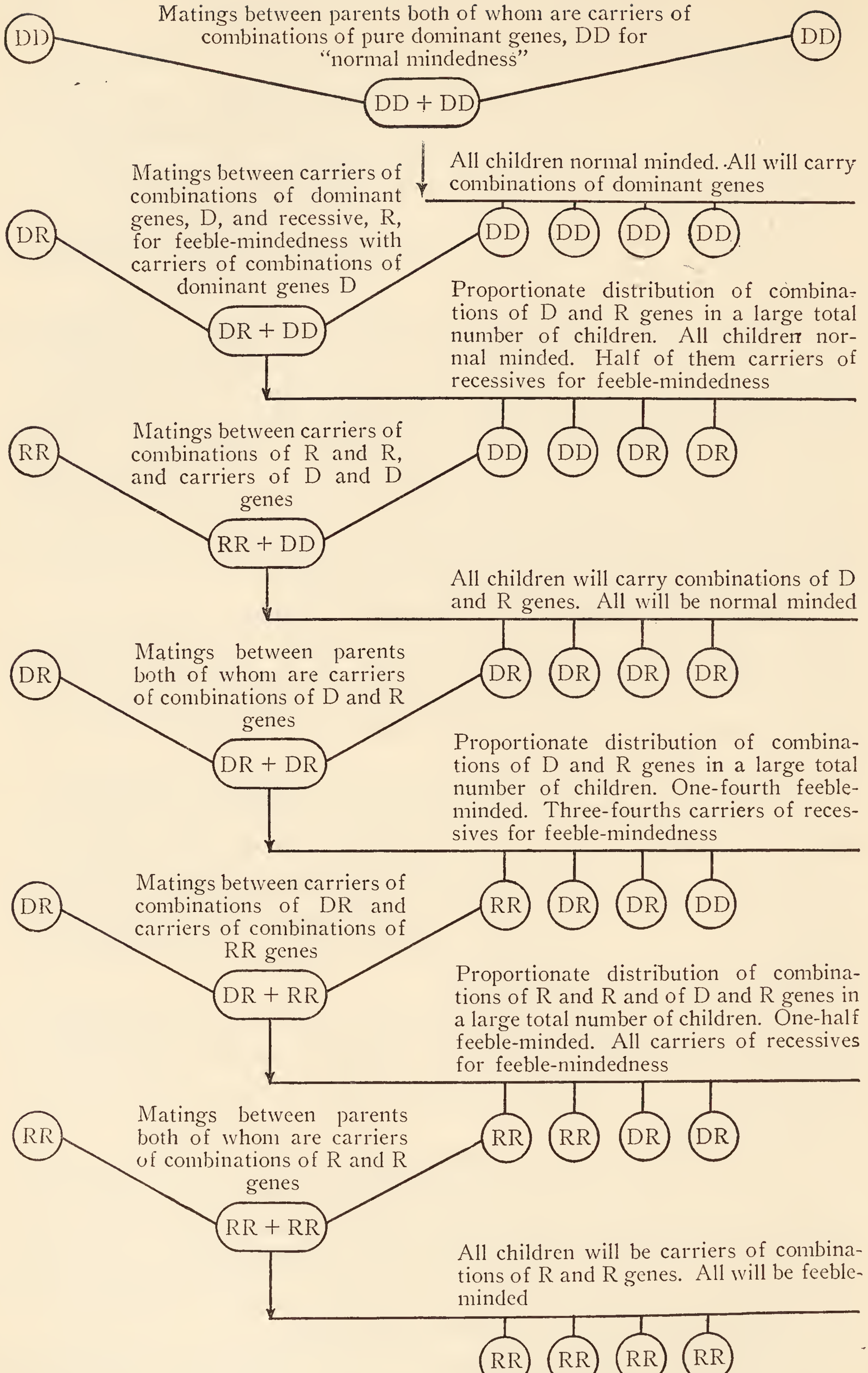


Fig. 52.—Examples of Mendelian matings between carriers of dominant or recessive or dominant and recessive genes with special reference to heredi-

tary feeble-mindedness. DD symbolizes germ-cells carrying dominant genes for normal-mindedness as contrasted with feeble-mindedness, transmitted from both parents. RR symbolizes germ-cells carrying recessive genes for feeble-mindedness received from both parents. DR symbolizes germ-cells carrying dominant genes for normal-mindedness received from one parent and recessive genes for feeble-mindedness received from the other.

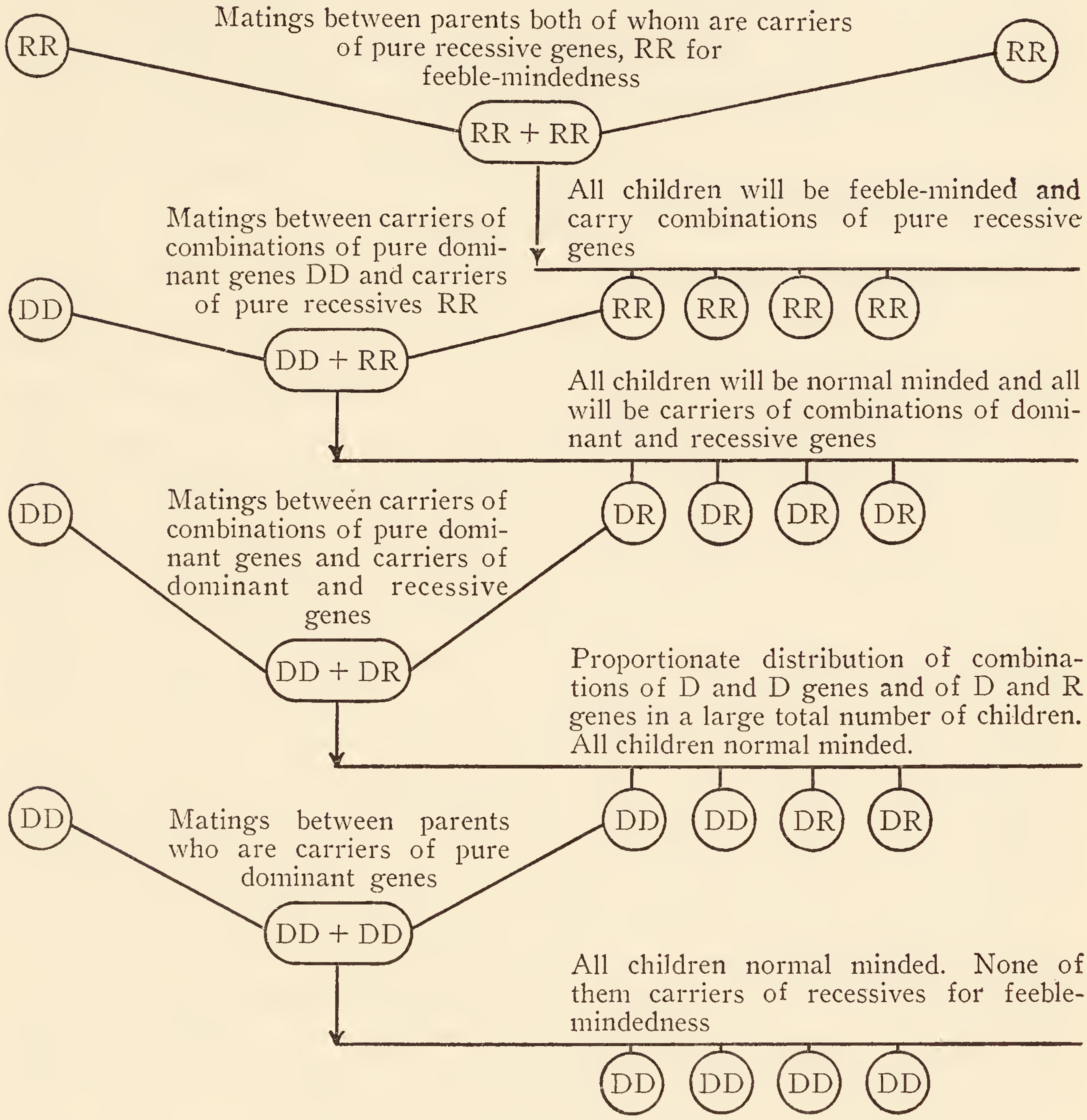


FIG. 53.—Examples of the possibility of breeding defects out with special reference to hereditary feeble-mindedness. The symbols are the same as in the preceding figure. Unfortunately, there is no known way in which desirable dominant genes may be selected with certainty and matings with undesirable recessives avoided.

genes for feeble-mindedness, none of the children will be hereditarily feeble-minded. They will all be normal so far as the exhibition of hereditary feeble-mindedness is concerned. But all these children will be carriers of the recessive genes of feeble-minded-

ness. Even though none of them will inherit a feeble mind, all of these children will carry the recessive genes of feeble-mindedness in one half their haploid germ-cells (i.e., their sperms or ova), and the dominant genes for the contrasting normal character in the other half. If one of these "50-50" carriers of recessive and normal contrasting dominant genes mates with a similar carrier, three-fourths of the children are free from the feeble-minded heritage and one-fourth are feeble-minded. Of the three-fourths born without the feeble-minded inheritance, two-thirds are carriers of pathogenic recessive genes for feeble-mindedness and one-third are free from such recessive genes.

Genealogies have been plotted for a number of families in which feeble-mindedness is common. While it is not possible to separate the influence of heredity from the influence of social and physical environment in these families, nevertheless the consistency of the genealogical history proves that heredity is one of the causes of feeble-mindedness, and that hereditary feeble-mindedness is a Mendelian recessive disease of common occurrence.

The story of the Kallikak family[1] is a record of two lines of descendants from a single father. One line is the result of an illegitimate mating during the Revolutionary War between "Martin Kallikak, Sr." (a fictitious name), and a feeble-minded girl. The feeble-minded son born of this union was "Martin Kallikak, Jr.," so named by his mother. Martin, Jr., married a normal woman in 1803. They had ten children. The other line was established after the war when Martin Kallikak, Sr., married a normal girl.

"Martin Kallikak, Jr.," the illegitimate feeble-minded son of "Martin Kallikak, Sr.," and the feeble-minded girl, became the common ancestor of a group of direct descendants that numbered 480 within a little more than one hundred years. The line of direct descendants from "Martin Kallikak, Sr.," and the normal mother numbered 496 in about the same period of time.

Of the 480 direct descendants from the feeble-minded mother, 143 were or are today feeble-minded; 46 were found normal; and the rest are recorded by Goddard as "unknown" or "doubtful."

Of the 496 descendants from the normal mother, all were or

[1] Henry H. Goddard, *The Kallikak Family, A Study in the Heredity of Feeble-mindedness* (The Macmillan Company, 1912, reprinted 1923). For criticism of Goddard's book see Abraham Myerson, *The Inheritance of Mental Diseases* (Williams & Wilkins Company, 1925), pp. 77 *et seq.*

are normal. Three are reported as "somewhat degenerate but . . . . not defective."

The 480 direct descendants by way of the feeble-minded mother married into similar families. The results of these marriages have been charted so that Goddard was able to secure records of 1,146 individuals carrying the heredity of Martin Kallikak, Sr., joined with that of the feeble-minded girl. This large group contains 262 records of feeble-minded progeny and 197 normal, the rest "undetermined."

The prevention of hereditary disease.—Many sorts of hereditary disease are merely deviations from the normal that bring no great disadvantage to the individual. Others, though serious, are rare. For instance, hemophilia is such a serious disease that only a few of the men who inherit it reach maturity. But the occurrence of heritages of mental defects and deficiencies, such as those that are responsible for a large percentage of the cases of idiocy, imbecility, feeble-mindedness, and the psychoneuroses, are so common and their cost to civilization because of accompanying dependency, delinquency, crime, and disease is so enormous that there is ample and compelling reason for insisting on the importance of prevention. Goddard in 1912 estimated that there were 300,000 feeble-minded persons in the United States of whom sixty-five per cent were hereditarily feeble-minded.[1] Gates, quoting Davenport, states that the great mass of idiots arise from feeble-minded parents. Statistical evidence proves that hereditary feeble-mindedness and other forms of serious defective mental heritage are excessively common among the inmates of jails, asylums, reformatories, and poor-farms, and among prostitutes—all of whom obstruct the progress of education and civilization, and place an enormous burden of expense upon society.

Methods of prevention.—The nature of the methods that will prevent hereditary disease is determined by the measures necessary for an effective control of the causes, carriers, or disseminators of these diseases. We know that hereditary diseases are caused by dominant or recessive factors contained in germ-cells. We are describing those factors here as "pathogenic genes." We know that the potent man or woman may be a carrier of pathogenic genes. Thus the man or woman with a hereditary disease is a carrier of the genes of that disease. We know, too, that men

[1] H. H. Goddard, *op. cit.*, p. 106.

and women may be carriers of recessive pathogenic genes without themselves having such disease. Thus, while it is estimated that three persons in every thousand of the total population of the United States have a heritage of feeble-mindedness, it is further estimated that one in any fourteen of the total population carry the recessive genes for feeble-mindedness.[1]

Finally, we know that the transmission of pathogenic genes from generation to generation and the appearance or recession of a heritable disease in succeeding generations are governed by laws of heredity described first by Mendel.

From these facts it follows that the prevention of hereditary disease may be accomplished only by preventing fertilizations by germ-cells that contain the genes of heritable disease. After such fertilization takes place the new life that develops in consequence under the continuing influence of environment and experience exhibits hereditary disease and becomes a carrier of the dominant or recessive genes of such disease in accord with the physiology of the chromosomes and the consequent Mendelian distributions described in the preceding pages of this text. Obviously, the prevention of hereditary disease is possible only through an effective control of the men and women who are carriers and potent disseminators of germ-cells that contain pathogenic genes. These carriers may control themselves or they may be controlled by such measures as (1) voluntary or enforced celibacy; (2) contraceptives; (3) surgical operations that obliterate the avenues of ovulation or insemination (e.g., vasectomy and salpingectomy), or removal of the reproductive glands or of essential reproduction organs.

None of these methods of control have yet proven practical. The carriers of dominant genes for known hereditary diseases are easily identified because such carriers always exhibit the disease sooner or later. Unfortunately, the delay in the appearance of the heritage of dominant disease may hide the evidence of the disease until after marriage has taken place and children have been born. But the vast majority of the carriers of recessive hereditary diseases are never known. For every individual who shows that he has a recessive hereditary disease there are many other individuals who exhibit no evidence of such disease, but who are nevertheless carriers of the genes of recessive heritable disease.

[1] R. Ruggles Gates, *Heredity and Eugenics* (The Macmillan Company, 1923) ; referring to East, p. 159.

Under our present limitations, these carriers give no understandable evidence that they are carriers. In the light of the knowledge we now have of the anatomy and physiology of the germ-cell it does not seem probable that we will ever have a practical method of identifying all the carriers of recessive pathogenic genes.

The individual has no control over the joint parental assortment of chromosomes that gave him life and furnished him perhaps with genes of hereditary disease. During his infancy and childhood he has no control over the environmental influences that emphasize or counteract his pathological heredity (i.e., his heritage of disease or tendency to disease). But with adolescence and the arrival of maturity he is more and more able in the majority of cases to make good in his program of health defense and health maintenance despite the handicaps of his heritage. His program of living, his relation to family hygiene, whether it be his own family or that of someone else, and his relation to public hygiene, must, wittingly or unwittingly, take into account the possibilities and limitations of health that are determined by his heredity. His preparation and plans for parenthood offer something of an opportunity for avoiding matings that would bring pathogenic genes together in ensuing generations and thus transmit a consequent heritage of disease to his children. Each prospective mate may consult a scientifically informed adviser and obtain the best available advice as to the wisdom of marriage with the mate he has in mind, or as to the wisdom of his ever marrying and having children.

The public as a whole has a serious obligation for the safeguarding of society from those very important hereditary diseases that exhibit themselves in heritages of idiocy, imbecility, feeblemindedness, and the various psychoses and neuroses. Some of these diseases may be prevented by preventing the matings of men or women who are potential transmitters of such diseases. Others may be controlled by providing the right sort of treatment for the inherited disease itself and the right sort of instruction to parents for the safeguarding of their children from damaging experiences and influences, against which they have inherited a weak defense or for which they have inherited a tendency.

Some of the ancient societies of which we have record destroyed all infant weaklings. Obviously, such a method of preventing an oversupply of weak and dependent citizens, either in a primitive society or in a cultured public, must fail to accomplish

its purpose. Of greater futility were the Grecian proposals (Plato) that all children born of immature parents, or of parents past their prime, should be destroyed. Theoretically, the belief of Lycurgus that children of bad breed should not be permitted to live was sound. Infanticide was common in ancient and early civilizations. The idea was not strange to the Spartans. It was and is practiced by savage and primitive people. But our standards today do not permit infanticide even for the protection of future generations. The modern proposal to prevent fertilizations by germ-cells that contain "bad human breed" is far better. The difficulty is that there is no way in which bad human breed can be identified in the great majority of cases.

In recent years governmental efforts have been made in various parts of the world to protect society from those heritages that cause dependency, delinquency, and crime. Legislation has thus been enacted providing for the sterilization under certain circumstances of men and women who exhibit evidence of the more serious heritable mental and social diseases. The methods of control adopted legislatively ordinarily employ vasectomy or salpingectomy for the purposes of sterilization. Vasectomy is a simple operation requiring only three or four minutes when done by a skilful surgeon. In this operation the duct that empties the testis is severed. The segment leading from the gland is left open so that the sperms may leave the testis and be emptied into the scrotal cavity without impediment. But the other segment of the severed duct is closed so that the sperms cannot leave the body. Salpingectomy is a more serious operation. It involves opening the abdominal cavity and severing the Fallopian tubes (one on each side of the uterus). The severed end of the tube leading to the uterus is then permanently closed, thus shutting off the accessibility of the ova to sperms (see Fig. 21, p. 135).

It is believed that these operations have no effect on the individual other than to make it impossible for him (or her) to have children.

If it were possible to find and sterilize all carriers of the genes of all the important hereditary diseases, such diseases would disappear. This, as we have noted above, is not possible. We have not yet identified all the hereditary diseases, nor do we completely understand all the hereditary diseases that have been identified. In addition, and this is the most important obstacle to the eradication

of hereditary diseases, we are in most cases unable to recognize the carriers of recessive pathogenic genes. The eradication of a recessive hereditary disease by sterilizing all men and women who exhibit that disease is a slow method, even if it is the best at our disposal. As an example, it has been pointed out that it would require two hundred and fifty generations, or about eight thousand years, to reduce in the United States alone the present estimated proportion of three feeble-minded persons per thousand to a proportion of one to one hundred thousand by merely segregating or sterilizing all those who are feeble-minded.[1]

Sources of advice on the defensive hygiene of heredity.— It is illogical and unsafe for the lay citizen to depend on his own information and judgment for the settlement of the problems of heredity that may come before him. The preceding chapters of this book give evidence of a body of scientific knowledge with which the great majority of men and women can only become distantly acquainted. For purposes of individual, family, or public hygiene it is of importance for the individual to understand the principles involved in the physiology of the chromosomes and in the laws of heredity. But the details of this knowledge can be known and safely offered for advisory purposes only by the experienced scientific student. For example, many of the abnormal or unusual conditions that are commonly regarded as hereditary are acquired during prenatal life. Such diseases are congenital and not hereditary diseases. The diseases of the expectant mother may be communicated to her unborn child. Abnormal positions or accidental pressures may injure the foetus, so that the infant may be born with a deformity. Thus occasionally a child is born with but one hand or with only one arm or with no arms. These are not inherited diseases. They are acquired. Or the communicable diseases of the family may be transmitted to the infant or young child so that such infections may appear to have been inherited. We have no evidence that acquired diseases ever become hereditary. It is possible for an acquired disease to damage the germ-cells and alter their chromosomes and the genes they contain, and these altered genes may cause heritages of disease in offspring. Thus the effects of an acquired disease may be transmitted by inheritance but the specific acquired disease is not itself heritable.

[1] R. Ruggles Gates, *op. cit.*, p. 159, referring to a statement of Punnett (1917).

CHAPTER XXIII

THE DEFENSIVE HYGIENE OF HERITAGE

Experience with internal and external environments.— The health achievement of any given individual is a product of the influence of his environment upon his heritage of health possibilities. The factors in heredity that influence health are multitudinous. We can only vaguely appreciate their number and complexity. Similarly, the factors in our physical and biological surroundings and in our social relations that influence heritage and thus determine the quality of health achievement are equally numerous, complicated, and imperfectly understood. With each individual this experience of heredity with environment begins with the union of the two germ-cells that gave him his heritage of life and all its possibilities of health. The fertilized ovum begins immediately an internal experience and an external experience of heritage with environment that determines its immediate health and the subsequent health possibilities of the individual into which that ovum may develop. The internal experience of the fertilized ovum, existing as a single cell for only a few minutes, is an experience of the various microscopic living organs within the ovum with each other and with the various lifeless compounds (proteins, fats, carbohydrates, salts, water, oxygen, vitamins, enzymes, etc.) that are present in the protoplasm of the ovum. These living organs and lifeless compounds it will be remembered are contained in the nucleus and the cytoplasm. Thus, the nucleoplasm and the cytoplasm and their contents furnish the internal environment of any single living organ (e.g., a chromosome) of the fertilized ovum. The external environment of the fertilized ovum is furnished by the walls of the Fallopian tube or of the womb of the prospective mother, depending on the location of the ovum at the time of its fertilization. Thus the fertilized ovum or any other single cell has an internal environment and an internal experience with that environment; and it has an external environment and an external experience. The health of the single cell depends on the nature of its experience with its internal and external environments. After a few hours the fertilized ovum has divided into a large number of cells that all together form an embryo. The life of each cell may be described as the experience of the cell with

its internal and external environments. And the experience of the embryo itself may be described as an internal experience and an external experience. Every cell within the embryo is a part of the internal environment of the embryo. All its living organs, all its internal secretions and internal excretions, all its blood, lymph, and other body fluids and tissue juices, belong to the internal environment of the embryo. The mechanical, physical, chemical, structural, and functional influences of each and every cell within the embryo are parts of the internal environment of the embryo.

The external environment of the embryo is furnished by the womb in which it resides during prenatal life. Thus, the external environment of the embryo supplies warmth, protein, fat, and carbohydrate fluid food, oxygen, water, vitamins, mineral salts, and, under normal conditions, all the other requisites for the growth and development of the embryo.

The same dependence on internal and external environment persists throughout the life of the individual. The problem of individual health is thus always a problem that is concerned with the experience of the health heritage of the individual with the internal and external environment of that individual. We have noted in the preceding chapter that one's heritage of health is sometimes impaired by inherited deficiencies or defects that make good health difficult or even impossible, regardless of the favor of environment. On the other hand, it is even more obvious that the environmental experiences of a life at any age period may be such as to injure or destroy its heritage of health no matter how good that heritage may be.

Organic and functional experience with environment.—It helps a little in our discussion to describe these experiences as organic (i.e., structural or anatomical) and functional. Obviously, this is not a precise classification. Nevertheless, it is useful for our purposes, regardless of the fact that all function is dependent upon structure and upon structural relations. Our classification recognizes the fact that some experiences are chiefly organic and that others are chiefly functional and that the organic experiences may be evident in structural alterations with consequent functional changes, while the functional experiences are evident in functional alterations with or without known structural changes.

Football injuries, track injuries, or the results of automobile accidents are good examples of damaging organic experiences that

injure health. A dislocation, a broken bone, or a pulled tendon are structural (i.e., organic) experiences that injure health, temporarily at least. Rapid eating, heavy meals immediately preceding vigorous exercise or athletic competition, excessive weight reduction for weight classification in boxing, wrestling, basketball, or fashion, are samples of obviously functional and organic experiences that may injure health temporarily or permanently. Envy, jealousy, anger, rage, fear, suspicion, anxiety, and worry are functional experiences with environment that may be evidence of poor mental health or of mental disease with no known evidence of organic involvement.

It is important to recognize the fact that the effects of organic and functional experiences vary in the different "age periods" of the individual. Our prenatal experiences are largely, if not wholly, experiences of nutrition and enormous cell multiplication. During the first eight days of its life the human fertilized ovum increases ninety thousand per cent each day. During the first month, this amazing structural growth continues, though at a greatly reduced rate. "As determined by the volume of the foetus, the ovum increases more than ten thousand times in size during this period."[1] The experiences of the unborn babe are variously called prenatal experiences, congenital experiences, or intra-uterine experiences. While these experiences are limited to those of cell multiplication, cell assortment, adjustment, and specialization, for the formation of tissues, and tissue arrangements for the formation of organs, they are experiences in which injuries from excesses, deficiencies, and deprivations of food essentials and of other essentials in the internal environment may easily lead to congenital injury. Mechanical, physical, or chemical agents may under unfortunate conditions lead to congenital health injuries. Finally, in this period, the pathogens that infect the mother may also infect the unborn child.

The experiences of infancy, childhood, youth, maturity, and senility bring their characteristic health hazards that may make these periods contributory causes of poor health.

It is important further to recognize the fact that each of these periods has its own grade or degree of special dependency. The nearest approach to independence comes to the healthy adult whose

[1] These statements are taken from the *Textbook of Physiology* by W. H. Howell, tenth edition, p. 1039.

native intelligence has been so educated as to enable him to measurably control and adapt himself to his environment. But even he is dependent upon the group of which he is a part and upon the society of which he is a member, a supporter, and a beneficiary.

Food deficiency and deprivation.—It hardly need be stated that deprivation of food is destructive to life. No one would question the statement that a deficiency of food injures health. But it is common to find that we think of a deprivation or a deficiency of food as a quantitative matter and not as a qualitative matter. It is, of course, essential that there be enough food, but this requirement includes the fact that it is essential that each of the food factors necessary to health and to life must be presented in adequate amount in the food that finally reaches the tissue cell. In other words, satisfactory nutrition depends, among other things, upon an adequate, balanced ration available in the capillary blood and in the lymph that surrounds the healthy tissue cell.

The most common and, nowadays, the most obvious food deficiencies occur in the dietaries of infants and young children. Malnutrition has long been a known product of food deficiencies in these early age periods. The mother whose breast milk becomes deficient in any of its requisite food constituents (proteins, fat, carbohydrates, vitamins, salines, or water) will have an undernourished infant unless the deficiency is discovered and remedied by correcting the mother's milk or by bottle feeding. The same may be said of the prenatal child and the nutrition furnished by the blood of the expectant mother.

Children of the pre-school age and children in the elementary schools are not uncommonly underfed. Such health injury is not necessarily consequent on a small amount of food. It may be, and often is, due to deficiencies in one food factor or another that give the child an unbalanced ration. In any age period, successful nutrition, and therefore good health and life itself, depends upon the absorption and utilization by the tissue cell of the chemical bodies that it must have for its structural and functional purposes. These chemical bodies, we have seen, are the proteins, fats, carbohydrates, oxygen, salts, vitamins, and water[1] that are brought to the tissue cell by the capillary blood in the soluble and specially prepared forms that permit their passage through the cell walls, and

[1] There may be other chemical bodies at present unknown that are essential to cell life and cell health.

their utilization by the microscopic organs within the cytoplasm and nucleoplasm of the cell.

These chemical bodies contain carbon, hydrogen, nitrogen, oxygen, iron, sulphur, phosphorus, chlorine, sodium, potassium, calcium, magnesium, iodine, and iron. No cell can remain healthy or continue to live in the absence of any one of these chemical elements. But no tissue cell may make use of any one of these chemical elements unless that element is brought to the cell in a form that can be absorbed by the cell and used by the microscopic organs within the cell. For instance, nitrogen is requisite to the life of the tissue cell. But the tissue cell cannot use nitrogen unless it is available in the form of amino-acid. The red cells in the capillary blood of the lungs are continually absorbing free nitrogen from the air in the lung spaces and distributing that nitrogen throughout the entire body, but these molecules of free nitrogen are never absorbed from the tissue capillaries by the tissue cells. The cells cannot use nitrogen in that form.

For these various reasons, deficiencies and deprivations of food essentials may be due to any one of a number of conditions. There may be a deficiency in the public market supply. When countries are at war, or when famines occur as a result of war, flood, droughts, or diseases of grains and of food animals, or from other causes, the supply of marketable food may disappear.

There may be a deficiency of food because of the financial inability of the individual to purchase. Poverty thus becomes a contributory cause of malnutrition, and even of starvation.

Ignorance of food values may result in an unbalanced food ration (dietary) in the home or in the order from the restaurant menu that supplies the family or the individual with plenty of certain necessary foods and with too little of others that are essential to health.

These influences are particularly injurious in the functional experience of the prenatal child, the infant, and the adolescent. War, famine, poverty, and ignorance probably contribute more to the malnutrition and starvation of infancy, childhood, and youth than all other factors combined.

Poor appetite, due to lack of exercise, or to excitement, depression, or apathy, or to finicky, nervous temperament, or to the vagaries of "the spoiled child," often contribute to the food deficiencies of the tissues and organs of the body.

In addition, any functional or organic influence that interferes with any one of the numerous physiological events that take place in the alimentary tract or in the blood and lymph circulation, or in the tissue-cell metabolism in their relations to the preparation of food for the tissue cell, the transportation of food to the tissue cell, or the utilization of food by the cell will lead to a nutritional deficiency or deprivation with consequent malnutrition.

Deficiencies and deprivations of respiratory "food."—Such deficiencies are not so common nor so obvious as those of the food we eat and the food we drink. Of course, asphyxiation is a dramatic example of the tragic effects of a deprivation of oxygen. Such experiences are accidental, suicidal, or homicidal, as a rule.

But we must recognize that there is a common health damage accompanying insufficient exposure to open-air conditions. Haven Emerson has stated that every comparison that has ever been made between the influences of indoor air and outdoor air upon school children has shown that the outdoor children are better off physically, mentally, and spiritually.

There are other factors than the amount of oxygen present involved in these comparisons of indoor conditions with outdoor conditions. Physiological research indicates that the degree of absorption of oxygen by the hemoglobin of the red blood cells varies but little if at all in response to changes in the amount of oxygen present in the respired air so that a deficiency in the respiratory food in the blood or in the tissue cell could occur only under extreme conditions. Nevertheless, the facts of experience are that the fresh out-of-door-air oxygen, because of its abundance or because of something that goes with it, is favorable to nutrition, growth, and development, and that on the other hand, indoor-air oxygen, because of its deficiency or because of something that goes with indoor conditions, is not favorable to nutrition, growth, and development.

Deficiencies and deprivations of water.—It is, of course, common knowledge that the total absence of the intake of water is fatal. A deficiency of water supply produces health damages that are not commonly recognized as due to inadequate water supply. Among these injuries may be mentioned concentrated, acid, irritating urine; constipation; and headache.

Deficiency or deprivation of protein food.—Physiological experiment and human experience have proved that a deprivation of

protein food results in health injury and, if continued, death. Recorded facts and their scientific explanation demonstrate that not all protein foods will sustain life. Proteins which are to be used for the construction of living protoplasm, or the manufacture of special products by the tissue cell, must first be broken down to their constituent amino-acids. There are some twenty of these amino-acids now known. Depending upon the kind of amino-acids which make up any protein we can classify it as an adequate protein or an inadequate protein. An example of an inadequate protein is gelatin. At the time of its discovery, gelatin was regarded as a wholesome, inexpensive food and was first used by the French government in hospital and other public dietaries. It was found, however, that the patients subsisting on these dietaries in which gelatin was the protein constituent lost health and life. Scientific investigation soon proved that the damage was due to the inadequacy of the gelatin protein to sustain life.

Deficiency or deprivation of protein food is of special seriousness to infants, young children, and adolescents. In these growing, developing periods of life, the tissue cells are building living protein structure out of the protein foods (amino-acids) that reach them. Relatively the amount of cytoplasm and nucleoplasm constructed is greatest in the prenatal infant. The multiplication of cells from a single fertilized ovum to some thousands of billions of living tissue cells in a period of about two hundred and eighty-seven days is a piece of complicated manufacture and constructive work in which every new cell must receive its infinitesimal particle of living structural protein. The postnatal construction of cell protein proceeds at a greatly diminished rate. Obviously, the injuries of a deficient supply of protein food would be greater during the periods of structural increase.

At birth the child weighs about six pounds. At the end of the first year, it weighs almost eighteen pounds. During the first eight days of prenatal life, it increases its weight ninety thousand per cent. During the first year of postnatal life, it increases its weight almost three hundred per cent. These weights represent not only increases in structural protein, but in larger degree increases in all the synthetic products of cell activity.

Fat or carbohydrate deficiency and deprivation.—These two foodstuffs have the same chemical content—carbon, hydrogen, and oxygen—with merely a difference in the arrangement of atoms

into molecules. Proteins have the same chemical content with the addition of nitrogen. The carbon in all three of these foodstuffs is used by the tissue cells for transformation of potential energy into kinetic energy and heat, and into all the varieties of functional energy that constitute the complex mental and physical life of the individual. Of the three foodstuffs the carbohydrates are the most important, and the proteins the least important, for these purposes, but they all serve these purposes. The starches, sugars, and fats are called fuel foods. They are peculiarly important in those periods of life that are characterized by muscular activity—childhood and youth. They are especially important to those people whose functional experience requires large expenditures of kinetic energy, e.g., athletes, soldiers, stevedores, truckmen, lumbermen, construction gangs, and coal heavers. Burgess Gordon[1] and others have noted a deficiency of blood sugar in marathon runners who were exhausted at the end of the race. The exhaustion and deficit did not occur in runners in subsequent races who were fed small amounts of sugar shortly before the contest.

A deficiency in carbohydrate food may be covered by fat food or by protein food, but the substitution of fat or protein for carbohydrates is not easily handled by the digestive tract, and digestive irritations follow that injure health. A deficiency in total carbon in the dietary from these three sources causes losses in weight and losses in strength that may lead to emaciation and debility with a consequent incapacity to meet the physical demands of daily life. These deficiencies are particularly injurious to infants and children.

Deficiency or deprivation of inorganic salts.—A dietary consistently deficient in any one of the essential inorganic salts will not maintain health and may become a cause of death. We have noted elsewhere that these essentials are iron, sulphur, phosphorus, chlorine, sodium, potassium, calcium, magnesium, and iodine. Fortunately, these constituents are present more or less commonly in various compounds in all our foods and in the water we drink. There are, however, certain important exceptions, either in the saline content of food or water, or in the conditions under which inorganic salts are made available to the tissue cells for their purposes.

[1] Burgess Gordon, "Effect of Exercise on the Circulation, Sugar Metabolism, and Other Factors," *Northwest Medicine,* July, 1926.

Phosphorus deficiency.—A very common disease known as rickets affects infants and growing children. Because of this disease there is a failure in the formation of their bones. Their legs, ribs, pelvic bones—in fact all their longer and larger bones—may be misshapen and deformed. If such children mature, they may be incapacitated by these deformities. A distorted rickety pelvis, forming a narrow birth-canal, is not uncommonly a cause of disaster at child birth leading to the necessity for Caesarean section, or to the loss of the life of the mother or the unborn babe or both.

Rickets is caused by three deficiencies. First, an examination of the blood plasma of a child with rickets gives evidence of a greatly reduced phosphorus content. No reduction of calcium is found. Second, rickets may be produced in laboratory animals by feeding them diets deficient in Vitamin D. Children with rickets are found to be living on diets deficient in Vitamin D. Adding foods that contain Vitamin D, such as yolk of eggs, butter and animal fats, leads to a rapid cure of rickets. Third, children with rickets recover rapidly if their body surface is judiciously exposed to sunlight or to artificial light containing the ultraviolet rays. Thus rickets is due to a deficiency in (1) blood phosphorus; (2) Vitamin D; and (3) exposure of the skin to ultraviolet rays. For reasons we do not yet understand, Vitamin D and sunlight control the proportions of calcium and phosphorus in the tissue juices that supply the bone cells with the chemical compounds they require for the manufacture of bone.

Iron deficiency.—A deficiency in iron in the red blood cells is one of the causes of simple anemia. Here again, the deficiency may not be a deficiency in the dietary of the individual. As a rule, ordinary mixed diets contain all the iron we need. It sometimes happens that the iron salts present in the food of a given individual are not in a form that can be used by the tissue cells of that individual. In these cases, the physician may discover and prescribe ways of administering iron that will meet the needs of his patient. In other cases, it is fair to assume that the deficiency in the iron of the red blood cells may be due to some defect in the secretion of red blood cells by the bone-marrow cells, but as a rule a deficiency in iron salts will be covered by the iron present in an everyday mixed diet given as a balanced ration.

Iodine deficiency.—A deficiency in the salts of iodine in food

and in drinking water is accompanied by an enlargement of the thyroid gland. This type of thyroid enlargement is called "simple goiter" in contradistinction to the serious goiters due to other causes. Adding appropriate compounds of iodine to food or drinking water usually causes the goiter to disappear. The thyroid is a very remarkable endocrine gland composed of two oval bodies in the front of the neck lying at the sides of the trachea or windpipe where it joins the larynx (i.e., the "Adam's apple"). There are accessory thyroids found lying below the thyroid along the sides of the trachea. The parathyroids are glands of different structure lying behind the thyroids. Destruction of the parathyroids causes acute toxic symptoms and death. Destruction of the thyroids produces slow malnutrition, emaciation, and death. A deficiency in thyroid tissue in infants is accompanied by stunted growth, arrested bone development, dry and hairless thickened skin, undeveloped reproductive organs, and dull, stupid mentality. This disease of infants is called "cretinism." In adults, a deficiency in thyroid tissue is followed by a thickening and drying of the skin. There is an increase in the storage of fat. The hair falls out. The individual becomes weak, listless, apathetic, and dull. This disease of adults is called "myxedema."

Both of these diseases are cured marvelously by feeding with dried thyroid tissue taken from food animals. The completeness of the recovery from cretinism and myxedema after feeding with thyroid tissue is one of the most dramatic and spectacular achievements of medical science. In 1915 a white crystalline compound was isolated from thyroid tissue. It was named thyroxine. This compound contains sixty-five per cent of iodine. Thyroxine is even more potent than dried thyroid in the treatment of thyroid insufficiency.

There are other serious types of goiter, such as, for example, "exophthalmic goiter" and "malignant goiter." The diagnosis of goiter of any sort should be made by the experienced and trusted physician. Any other source of information or advice is a hazard of health and of life.

Simple goiter due to a deficiency of iodine may be prevented by including appropriate doses of iodine compounds in food or drinking water. In some cases, untreated goiter leads to one or another form of serious thyroid disease. These cases may not be benefited by iodine.

Simple goiter of adolescent children, due to iodine deficiency, is common in the United States in the region of the Great Lakes and in the Northwest. It is very much more common with girls than boys. Some communities report very successful results from the addition of iodine compounds to drinking water.

Vitamin deprivation and deficiency.—The existence of at least five of these amazing and mysterious nutritional requisites has been scientifically proved.[1]

A number of other vitamins have been announced, but not satisfactorily proved. It is probable that future research will establish some of these and find others than those now under observation. These five are generally designated as Vitamins A, B, C, D, and E. Vitamin A is designated as "fat-soluble A—growth-promoting vitamin"; Vitamin B as "water-soluble B—antineuritic vitamin"; Vitamin C as "antiscorbutic vitamin"; Vitamin D as "antirachitic vitamin"; and Vitamin E as "antisterility vitamin." (The antisterility is descriptive of its effect on laboratory rats.)

Until recently only Vitamins A, B, and C were known. Funk in 1922 suggested "Vitamin A" for what was then believed to be the antirachitic vitamin. McCollum has shown that Funk and others were dealing with two vitamins, one a growth-producing vitamin, and the other an antirachitic vitamin. For this reason Vitamin A is now known as a "growth-producing vitamin," and the antirachitic vitamin is designated as "Vitamin D." Vitamin E is a discovery that has recently (1923) been made in some experimental work done with rats. Evans and Bishop report sterility of female rats on a diet lacking in Vitamin E. Fertility is restored when Vitamin E is replaced.

Thus the nomenclature of the vitamins is descriptive of diseases of deficiency or of deprivation. It is based on the fact that a deficiency of any one of them is a cause of, or is associated with, a very important disease—Vitamin A with arrested growth, Vitamin B with beriberi, Vitamin C with scurvy (known also as scorbutus), Vitamin D with rachitis (or rickets), and Vitamin E with sterility in laboratory rats. If, in the course of any one of these diseases, the vitamin deficiency that caused the disease is

[1] See William H. Howell, *Textbook of Physiology* (W. B. Saunders Company, tenth edition), p. 928, for a brief description of the vitamins. A more detailed discussion will be found in *The Newer Knowledge of Nutrition* by E. V. McCollum and Nina Simmonds (The Macmillan Company, 1929).

satisfied before the disease has caused irreparable destructive injuries, recovery follows with amazing rapidity.

Foods deficient in vitamins.—Vitamin A is absent "from vegetable oils, vegetable margarines, skim-milk, skim-milk cheese, white flour, pure cornflour, polished rice, custard powders, glucose, cane sugar, beet-root sugar, syrups, egg substitutes, meat extracts, proprietary foods, highly refined foods, hydrogenated and hardened fats, and white fish."[1] Vitamin A is destroyed by exposure to light and air (drying), and sterilization by ultraviolet rays.

Vitamin B "is absent from polished rice, white flour, cornflour, sago, tapioca, arrowroot, custard powders, egg substitutes, pea-flour, butter, cream, purified cod-liver oil, meat extract, distilled and malted liquors, tea, and malted coffee; and is very deficient or wholly lacking in the refined foods of the modern food industry."

Vitamin B is not affected by ordinary cooking, but is destroyed in large measure by the high temperatures necessary for the successful canning of foods. It is dissolved out of foods in boiling, but remains active in the water from such boiling.

Vitamin C "is absent from animal and vegetable oils, tinned meats, and practically so from cereals and pulses or their food derivatives. It is absent also from yeast and from distilled and malted liquors made according to European methods."

Vitamin C is destroyed by heat and drying. It is more stable in the presence of fruit acids and is destroyed by alkalis such as cooking soda. Acid fruits, such as the orange, may be dried without immediately destroying their content of Vitamin C.

Vitamin D is more abundant in cod-liver oil and in the yolk of eggs.

Vitamin E is present more abundantly in green vegetables and in cereals. It is deficient in meats, fish, milk, and cod-liver oil.

The following foods contain no known vitamins: cocoanut oil, cottonseed oil, lard, margarine from vegetable fat or lard, meat extract, milled cereals, olive oil, polished rice, pork fat, pure cornflour, sugar, and white flour. Vitamins A, B, C, and D are each essential to health, and, with the possible exception of Vitamin A, to life. We do not as yet know the significance of Vitamin E to human health. A dietary made up of the foods above would be injurious to health and would eventuate in death.

[1] Robert McCarrison, *Studies in Deficiency Diseases* (Oxford University Press, London, 1921), pp. 17–22.

Diseases due to vitamin deficiency.—As indicated by their names, the diseases of human beings that are now known to be caused by vitamin deficiency, and therefore prevented, cured, or improved by vitamin sufficiency, are rickets, scurvy, and beriberi. There is evidence that, in addition to these three well-defined diseases, there are various disturbances of the stomach and intestines and of the functions of the endocrine glands, the heart and blood vessels, and the brain, cord, and nerves that are consequent on or related to deficiencies or deprivations of Vitamins A, B, C, or D. These effects of vitamin deficiency may occur independently of beriberi, scorbutus, or rickets.

Rickets is a universal disease of deficient nutrition. We discussed this disease above in connection with calcium and phosphorus deficiency. It is most common with artificially fed babies in the first and second years of life. "Condensed milk, together with proprietary foods, as well as a one-sided carbohydrate diet, leads almost invariably to the development of rickets" (Funk). That it does occur in all age periods was proved by the experience of the countries that suffered extreme food deficiencies during the World War. This experience indicates that the difference between the rickets of infants and children and the similar bone disease (osteomalacia, or softening of bone) in adults is largely due to the difference in the age (maturity) of the bones in these periods. Rickets of infancy is characterized by cartilage and bone deformity, retarded or arrested growth, and retarded or arrested mental development.

Rickets is apparently caused by deficiencies in amounts and by inappropriate relationship of phosphorus and calcium and of Vitamin D and skin exposure to ultraviolet rays. The disease is cured by giving an appropriate balanced food ration containing sufficient Vitamin D, as in cod-liver oil, and by judicious direct exposure of the skin to sunshine or ultraviolet rays.

Beriberi is one of the oldest recorded diseases of mankind. Casimir Funk[1] notes that it was described by the Chinese in 2697 B.C. in *Neiching,* the oldest known medical book. This disease of vitamin deficiency is characterized by loss of motion and sensation (motor and sensory paralysis), dropsy, heart affections, extreme weakness, and emaciation. A medical description of the dis-

[1] Casimir Funk, *The Vitamines* (Williams & Wilkins, 1922), p. 278.

ease would present a large number and variety of details that need not be mentioned here. Like many other well-known diseases, beriberi may be present in a latent or "preclinical" form and escape notice because the evidence of its presence is ill-defined and vague.

Beriberi is most common in Eastern Asia and Polynesia. Within recent years there have been as many as fifty thousand recognized cases annually in Japan. The mortality in some regions has been as high as sixty and seventy per cent.

This disease is caused by a deficiency of Vitamin B—the anti-beriberi vitamin. It occurs chiefly in Eastern Asia and Polynesia because the diet in that general region is very largely polished rice. When rice is polished the shell, or pericarp, is removed. There is no Vitamin B in the polished (i.e., shelled) grain. There is enough Vitamin B in the shell of the rice grain to prevent beriberi in the great majority of cases. When unshelled rice forms the diet the occurrence of beriberi has been reported as one case in ten thousand.

The disease may be cured by introducing rice bran or unshelled rice into the diet. Of course, other foods containing Vitamin B may be used more effectively in countries in which rice is not the chief or only food.

Beriberi is common in Brazil and surrounding countries in which the food ration customarily contains little or no Vitamin B. It occurs also along the East African coast. Outbreaks have been rarely recorded in the United States. Cases have been observed among the Chinese in California. An outbreak is recorded in a prison in New Jersey, caused by a monotonous diet of white bread. Cases have been reported in Kentucky.

Beriberi has been noted in hospitals, asylums, and prisons in which the food supply contained an inadequate amount of Vitamin B.

Scurvy, or scorbutus, a disease characterized in adults by great debility, anemia, spongy bleeding gums, and a tendency to hemorrhage, has been known for hundreds of years. It is a part of the tragic history of every long war. It was a part of the history of every long sea voyage prior to the discovery of the antiscorbutic values of fresh vegetables and fresh meats. The famous voyages of Captain Cook were made possible by his conquest of scurvy. At the end of one voyage, beginning in 1772, he had covered over twenty thousand leagues (nearly 75,000 miles), had been en route

more than a thousand days, and had lost only one of his 118 men. No such freedom from scurvy had ever before been achieved.

In the Civil War in the United States there were 30,714 cases of scurvy because of the use of dried vegetables in winter.

During the World War, thousands of cases were observed, and it is likely that no single army was entirely immune. Hehir describes numerous cases among the Indian troops in Mesopotamia who refused to eat meat because of religious scruples. Turner states that thirty to fifty per cent of these troops developed scurvy. . . . .[1]

In 1917 scurvy was reported in the poorhouses of Glasgow and Newcastle, and in a health report from the city of Manchester, England.

Infantile scurvy (Barlow's disease) is found only rarely in breast-fed children. It occurs commonly in children of the nursing age who are fed on over-heated milk or milk that has been heated too long, as in over-pasteurization. Over-heating ("30 minutes at 145°," Hess) destroys the antiscorbutic vitamin in milk. The early symptoms of infantile scurvy are loss of weight or failure to gain, restlessness, and pallor. Later, the joints become swollen and tender, especially the knees and ankles; motion is painful; the gums bleed and there may be bleeding from the nose and other mucous surfaces. Slight bruises cause hemorrhages in the region of injury. Finally, there is marked general weakness and anemia. If the vitamin deprivation continues, death results. The disease is easily cured by antiscorbutic foods.

Scurvy will not occur if orange juice, lemon juice, tomato juice, or some similar antiscorbutic is added to the diet. The disease is cured by adding antiscorbutic foods to the dietary, provided the disease has not been permitted to cause too much damage before treatment.

Pellagra is a disease characterized by a specific erythema of the skin, severe stomach and intestinal disturbances, and serious degeneration of the central nervous system. It has been a common disease in northern Italy, Rumania, southern Tyrol, and North America. It is a disease of food deficiency. According to Goldberger[2] the following may be the causes: partial lack of the

[1] Casimir Funk, *op. cit.*, p. 299.

[2] Joseph Goldberger, and G. A. Wheeler, *The Experimental Production of Pellagra in Human Subjects by Means of Diet*, Hygienic Laboratory, Washington, Bulletin 120.

vitamins now known; lack of animal protein; lack of an unknown vitamin; or the combined influence of all these factors.

This disease is most frequent and severe among the poor in Texas, Arkansas, Louisiana, Mississippi, Kentucky, Tennessee, Alabama, Virginia, North and South Carolina, and Georgia. There were 5,418 fatal cases in the United states in 1927. During the years 1915 and 1916 it was estimated that there were about 165,000 cases in these Southern states.

In the United States the death rates in asylums have been as high as fifty per cent; in private practice, twenty to twenty-five per cent.

Pellagra is caused by faulty diet. The researches of Joseph Goldberger and his associates have established that fact, but there is doubt as to the nature of the deficiency responsible for the disease. It may be caused by a deficiency of adequate protein, but the evidence points rather to an unknown factor, perhaps a vitamin. Goldberger describes "Vitamin PP" as the cause. Pellagra is prevented or cured (if treated in time) by a dietary containing adequate amounts of fresh milk or fresh meat.

Summary of defenses against food deficiencies.—From the foregoing facts concerning health injuries due to deficiencies and deprivations in the essential factors contained in the food we eat or the food we drink (water), it is obvious that ordinarily these inadequacies involve more than one essential factor. A dietary deficient in vitamins is likely to be deficient in adequate proteins or fuel foods, or salines. A balanced ration containing ample amounts of all the food requirements is the safest food supply for the table. Such a dietary should contain adequate amounts selected from each of the following groups: (1) whole meal bread or nuts, eggs, or animal tissues; and (2) whole milk, or butter, or animal fat; and (3) fresh fruit and green vegetables. If all the foods in any one of these three groups are in insufficient amount or absent, the dietary will be deficient. A prolongation of such deficiency will lead to health injury.

It is unwise to subsist upon a ration in which there is only the minimum supply of any one factor essential to health. The food ration consumed by the individual should have a liberal supply of all the essential food factors.

CHAPTER XXIV

FOOD AND OTHER EXCESSES

Food excesses that lead to health injury.—Excess of water as a food factor may be a source of indigestion. A glass or two of water at meals, and a glass or two between meals, with a total of six or eight glasses of water a day is a reasonable amount and desirable for bodily health. More than that amount at meals may lead to an interference with digestion. A larger amount desired between meals may be an indication of diabetes. A persistent excessive thirst for water should lead to a medical examination. The excess of water received in this case is not a cause of diabetes. It may be an effect of diabetes.

Excess of protein food is regarded by some competent observers as a cause of injury to the kidneys leading to various forms of kidney diseases (Bright's disease). These students present evidence that leads them to believe that excesses of animal proteins (meats, principally) are accompanied by the production of internal excretions that irritate the kidneys because of the greater and more irritating excretory work they must perform in removing those excretions and eliminating them in the urine.

Excess of protein foods, particularly the red meats, unaccompanied by roughage (e.g., lettuce, spinach), leads to sluggish intestinal excretion. Undigested meat residues may accumulate in the large intestine. Putrefaction follows. Its products are absorbed through the walls of the large intestine into the capillary blood and become distributed throughout the blood circulation. As a result the excess of meat protein becomes a source of health injury known as auto-intoxication. This composite health injury is characterized by bad breath, headache, acne (pimples), irritable disposition, and a variety of intestinal, circulatory, and nervous discomforts.

Excesses of fats and carbohydrates are common characteristics of the dietaries of humans. This statement is much more true of carbohydrates than of fats. Starches and sugars (carbohydrates) are the main factors in cereals, breads, and pastries; and sugars are the large and essential constituents of candies, ice creams, and soft drinks. But fats in the form of cream and butter are common factors in these foods and drinks.

The most common of the injurious effects of excesses of carbohydrates and fats in the dietary are intestinal irritations, indigestion, skin eruptions, and obesity. These health injuries are particularly common to people who eat sweets between meals. Children and young people generally give good examples of these injuries, particularly during holiday seasons. College students, clerks, and stenographers are notorious for lunch habits that give them excesses of pastries, confections, candies, and sweet and soft drinks for which they pay with stomach-ache, indigestion, bad breath, pimples (and other skin-eruptions), headaches, eyeaches, and other more serious health injuries.

In this connection it is important to note that the large increase in sugar consumption in the United States and the large increase in the number of people in the country with diabetes is regarded by some observers as significant of a causal relationship. It is logical to assume that an excess of sugar eaten by the individual would overtax the capacity of his pancreatic glands to secrete enough insulin to take care of the excess. One must admit the possibility and the probability that too much sugar in the dietary causes diabetes in people with inadequate insulin secretion.

Excesses of the inorganic salts are not common. Under some circumstances it is believed that people may use too much table salt. This is the only inorganic salt that is added to foods as a matter of culinary routine. People with "heart-burn" or "acid stomachs" sometimes find relief in omitting the addition of salt to their foods. The other salts are commonly present in all our edible foods and drinking waters in amounts that do not ordinarily vary into excess. The foodstuffs that contain excesses of inorganic salts are likely not to be palatable and, therefore, are not eaten. An unusual desire for table salt should be referred to the family physician for safeguarding explanation.

Vitamin excesses are unknown so far as our present knowledge goes.

Excretory deficiencies, deprivations, and excesses.—These functional experiences are intimately associated with nutritional experience, but the external excretory functions are so distinct that the whole group deserves separate consideration. These functions, like those of nutrition, are largely subject to physiological influences over which there is no direct voluntary control. Any anatomical or physiological condition that leads to a deficiency, or

excess, of internal or external excretion would be a source of health injury. A cessation of kidney excretion, intestinal evacuation, or respiratory excretion leads to very serious consequences. Prompt and adequate excretion is essential to health. Interference with the normal excretory action of the kidneys, the bowels, the skin, the lungs, or the uterus is a menace to health. Fortunately, these functions go on largely without any conscious effort on the part of the individual. They are a part of our autonomic defensive hygiene. This is, of course, wholly true of the internal excretions. We do, however, have a habit relation to, and therefore some influence on, the functions of defecation and sweating. We may influence urination and defecation indirectly by the amount of water we drink and by the amount and kind of food we eat.

Deficient fecal excretion is called constipation. This condition may be brought about by a dietary lacking in bulk food (roughage) such as milk, spinach, lettuce, and whole-meal bread. It may be due in part to insufficient water. It is most commonly a result of careless habits through which the individual neglects to secure a natural, adequate defecation regularly at set times once or twice every day without the aid of cathartics or other artificial measures.

The health damages due to deficient fecal excretion include various abdominal troubles that frequently require surgical operations for their control and for the prevention of imminent death. The lesser, though hazardous damages, include abdominal pain, pimples and other skin troubles, bad breath, headache, dizziness, diminished alertness, and lack of energy. The common diagnosis is "auto-intoxication."

Deficient excretion from the skin is not of very serious importance. Infrequent sweating and obstructed sebaceous discharge have parts to play in the production of skin trouble. Acne is the most common of these results. Sedentary life with no vigorous physical exercise, no sweating, no bathing, and no rubdown with a coarse towel, is a combination that leads to a deficiency of the various excretions from the skin as well as to more serious health damages that are discussed elsewhere.

A deficient excretion of urine is a matter of serious importance unless it is a result of drinking too little water. Even in that event the ultimate result may be serious. The deficiency of water is accompanied by a concentration of the urine. It becomes acid

and irritating and is regarded as a probable source of kidney irritation and consequent disease. If the amount of urine voided in twenty-four hours is much less than 1,500 cc. with a dietary made up of a balanced ration and plenty of fluid, the matter should be referred to the family physician.

A deficiency or cessation of menstrual flow at appropriate intervals should be referred to the family physician.

Excretory excesses.—(*a*) A greatly increased amount of urine voided in a twenty-four-hour period may be due to large amounts of water or other fluids, drink, nervous excitement, or disease. (*b*) Frequent large movements of the bowels (diarrhoea) may be caused by indigestion, nervousness, intestinal infections, or the irritations of cathartics. (*c*) Excessive sweating may be due to nervousness, heat, or physical exercise. (*d*) Excessive respiratory activity follows physical exertion and accompanies certain injuries to the lungs, the heart, or the blood circulation. (*e*) Excessive and frequent menstruation is practically always an evidence of health injury that should receive expert scientific attention.

Deprivation, deficiency, or excess of physical exercise.—We have noted elsewhere in this book that the functional experience of 500 voluntary muscles with which each individual is furnished is one of the factors that determine his health. These organs represent over forty per cent of the body weight. They are furnished with some sixty thousand miles of capillary tubing through which they receive their supply of foods specially prepared for their internal environment, and into which they discharge their products, wastes, and rejections. Over two million nerve fibers (axis cylinder processes) connect them with the nerve cells of the spinal cord and brain, bringing them into a co-operating service relationship with some thirteen billion neurones of the cerebral cortex, and every one of their several hundred million constituent muscle fibers has its own motor end plate (receiving apparatus) on the end of a twig of one of those efferent (voluntary) nerve fibers. And every bone and every joint of the whole body is moved or controlled by groups of these muscles. This complicated organization of myriads of living cells that bring together the machinery, power, and government of purposeful voluntary movement in the long process of evolution has given man intelligent mind; educated his intelligence; and enabled him to control his environment. Over two thousand years ago

Anaxagoras (500–428 B.C.) taught that man's intelligent mind, as contrasted with the instinct mind of animals, is a realization of the possibilities that came when Nature gave him hands freed from the slavery of locomotion. No other creature has such hands.

Adequate general physical exercise is thus a functional use of the voluntary muscles and of all the other organs that must function whenever the voluntary muscles function. Adequate physical exercise is, therefore, necessarily a usage of all or practically all the organs of the body. Thus, general usage of the voluntary muscles means an accompanying usage of most if not all the four trillion fixed living cells and the twenty-two trillion floating cells of the body. In accord with the inexorable biological law of use, adequate physical exercise, in the absence of more powerful adverse influence, must contribute to the maintenance or improvement of the health of the whole individual, mentally, physically, socially, and spiritually, and a deficiency or deprivation of physical exercise must lead to a proportionate health injury. These effects are particularly evident in the life of the growing, active, play-hungry child.

Effects of deprivation of physical exercise.—A deprivation of exercise is a complete absence of exercise. When one breaks an arm, the muscles that ordinarily move the bone that has been broken are deprived of exercise, while the bone is healing. The physician holds the arm at rest with splints and a sling. If the muscles are deprived of exercise for a period of several weeks they will be diminished in size and weak when the splints are removed. Their size and strength may be restored by exercise. The same loss in size and strength of muscles occurs when one sprains a joint so badly that it must be held in one position without movement for a considerable period of time. The physician nowadays in taking care of a fracture or sprain is anxious to reduce the period of immobility (deprivation of exercise) to as short a time as possible in order to avoid excessive muscular wasting and weakness. He recognizes the importance of the law of use.

If the motor nerves of a group of muscles are paralyzed they no longer transmit motor-nerve impulses to the muscles. Consequently, such muscles are paralyzed and they are therefore deprived of exercise as a result. They slowly diminish in size until they are merely thin strands of degenerated muscular tissue. Such

muscles are described as "atrophied muscles." They are common results of infantile paralysis.

If a joint becomes stiff and without motion, as often happens in various forms of arthritis, the muscles that once moved the bones that form the joint are deprived of exercise. A disease of the joints known as rheumatoid arthritis, fortunately not very common, sometimes affects many or nearly all the joints of the body, locking them with bony deposits so that motion in them is no longer possible. In these tragic cases the voluntary muscles related to these joints are correspondingly deprived of exercise. They atrophy. If the locking (ankylosis) affects many joints and therefore many muscles, the atrophy and emaciation consequent on the enforced deprivation of exercise becomes extreme.

When a muscle atrophies, the nerve-cells that formerly sent the nerve impulses which caused the muscle to contract, do its work, and play its part in the various activities of the individual have no longer any function to perform. They, too, are deprived of activity. Therefore, they atrophy.

When a child is born without an arm, the nerve-cells that would have supplied the muscles of the arm with nerve impulses never develop.

If an infant, normal at birth, were so unfortunate as to lose completely its power of voluntary movement save taking food, with no accompanying loss of other functions as they exist at birth, none of the motor nerve-cells would develop; there would be no stimulus for bodily growth or development; no possibility of mental action involving imitation or response to suggestion; no education of the higher mental centers. It is not believable that such an infant could live for a very long period of time. Fortunately, no such complete deprivation of exercise is possible in the life of the infant or in any other age period of the individual.

Thus, in accord with the biological law of use, a muscle deprived of all exercise diminishes in size; its fibers become small and weak and finally degenerate. Such a muscle is an "atrophied" muscle. The nerves that should stimulate it become "atrophied" nerves. A muscle will not recover from a prolonged period of atrophy, nor will its nerve-cells recover.

Effects of deficient physical exercise.—Growth and development depend in part on the physical exercise (and play) of infancy and childhood. Deficient physical exercise in these periods means

insufficient stimulation of (1) metabolism; (2) organic growth; and (3) functional development. Such children do not grow as they should in height and weight, and they fail to achieve the normal development of mind, character, and personality that is so dependent on the voluntary play life of the child.

With insufficient exercise the voluntary muscles are weak; they lack endurance; and they fatigue easily. Since exercise of the skeletal muscles necessarily exercises the muscles of the heart and circulation and of respiration, it follows that a deficiency of physical exercise means also weak, easily exhausted muscles of the heart and circulation and respiration.

Thus, the individual who is a victim of a program of living that is deficient in physical exercise is handicapped by weak, incompetent voluntary muscles, untrained and undependable heart and circulation, and an untrained, inadequate respiratory control. As long as his life is one of sedentary uneventfulness, his weaknesses may not betray him, but he will be useless or defenseless in the emergency of an accident, a catastrophe, or war, or in face of a need for fight, flight, or rescue.

Physical exercise gives us our most important influence over metabolism. The amount of calories necessary to satisfy the physiological needs of a given individual depends on the amount of physical exercise (muscle work) he does. The football player requires much more than the spectator. The student in the lecture room or library requires less than the student on a collecting trip. The man in the auto needs less than the man on the hike.

Trouble arises when one satisfies a football player's appetite and neglects to take a football player's exercise.

Insufficient physical exercise, poor appetite, and underweight in people under thirty or thirty-five years of age is significant of poor health, and justifies anxiety as to the future. The poor appetite and the hazardous underweight may both be consequences of the deficient physical exercise.

Deficient physical exercise, good appetite, and overweight past the age of thirty or thirty-five establish a health hazard. The program, then, should be one of adequate and appropriate physical exercise with the "good appetite" satisfied by an appropriate dietary. The overweight would then disappear.

Deficient physical exercise and the diseases of deterioration.—Within recent years attention has been called to the fact

that the death rate from physical depreciation, as shown by degenerative changes in the kidneys, the heart, and the arteries, is greater in the later age periods in the United States than in Norway, England, and various other countries. It has been urged that these organic deteriorations are due to the fact that men of today in this country did not have the active, vigorous childhood and youth that characterizes those earlier age periods in these other countries.[1] It is stated, too, that adults in the United States do not as a general rule secure the benefits of habitual reasonable programs of physical exercise, and that the adult population of Norway, England, etc., does in general enjoy such programs. On the basis of this reasoning it is maintained that our excessive rate of mortality from degenerative diseases of the kidneys, the heart, and the arteries is due to the deficiencies in physical exercise that characterize youth and maturity in this country today.

While this contention is a logical one, it cannot be regarded as proved. Nevertheless, it must be admitted that the physiological consequences of sedentary inactivity during childhood and maturity would necessarily produce a weak, untrained, and inefficient heart and circulation, and that such a sedentary life might throw an excessive burden on the kidneys.

"Adequate" and "sufficient" physical exercise are relative terms. Whether a daily habit of physical activity is deficient or adequate depends on the character of the daily program. On the one hand are the regular demands of the day's routine. On the other are the probabilities of emergency demands for which it is reasonable to expect the individual to be prepared. The daily program and the high physical emergency expectation of the fireman and the routine of the bookkeeper offer contrasting requirements for appropriate physical exercise. A program that would be adequate for the preparation and maintenance of the bookkeeper would be deficient for the fireman. The amount and kind of exercise necessary for the adequate training of the soldier even in times of peace is quite a different program from that which is adequate for the "average" citizen.

The need for vigorous, enduring muscular strength trained in the skill of warfare and defense against man and beast is no longer a constant requirement in the civilized world. Our ancestors de-

[1] Clark W. Hetherington, *Shall Military Training Be Given Our Youth?* Senate Document No. 22, 65th Congress, pp. 3–6.

pended on their muscles for the preservation of their lives, their health, and their property. It may be said, too, that the necessity for hard muscular work in order to secure food and clothing, provide shelter and protection from the elements, and gain the satisfactions of social life is not so common today as it was to most of mankind not so very long ago. But there is still ample necessity for reasonably competent muscular development and reasonably skilful muscle control. Men and women have to work and must depend on their muscles in order to meet the demands of daily life. At one time or another most of us have to toil hard in pursuit of our peaceful occupations for the welfare and health of our families, our communities, or ourselves. Wars are not yet merely episodes of a historic past. And strength and endurance are required on occasion today in order to defend one's health and life in the emergency of a great fire, such as that of San Francisco in 1906; or of a great flood, of which the Mississippi Valley furnished a colossal example in the spring, and New England to a smaller but nevertheless tragic extent in the autumn, of 1927; or of extensive forest fires such as those that visit various parts of the United States every summer. Reasonable muscular strength and reasonable muscular endurance are requisite to the protection of health and life every day at street crossings in the busy traffic of great cities. They are a necessity in the life of every man or woman actively engaged in the toils of labor, industry, business, or professional occupation. It cannot be doubted that ample physical exercise in the periods of childhood and youth play a real part in defending and safeguarding the health of maturity, nor can it be wisely urged that regular habits of physical exercise during adult life are not useful and important habits of defensive hygiene.

The more obvious injuries or hazards to health and life that are caused by deficient physical exercises are: (1) weakness and lack of endurance of the neglected voluntary muscles; (2) weakness and lack of endurance of the muscles of the heart and circulation; (3) weakness and lack of endurance of the muscles of respiration. It is logical to believe, but convincing proof has not yet been furnished, that the sedentary life produced by deficient physical exercise during youth and maturity hastens the organic deteriorations that cause the diseases of degeneration.

It is a significant fact that physical exercise is one of the com-

monest prescriptions of the successful physician and one of the very common recommendations in the best textbooks on treatment. And there is probably no one of us out of his teens who has not at some time or other experienced the mental and physical discomfort of sluggish inactivity and the bodily and mental exhilaration of a return to a program of interesting vigorous exercise.

Health effects of excessive physical exercise.—The amount of activity necessary to make physical exercise excessive depends on the condition of the individual and the nature of his activity. His condition at any given time is a product of his heritage and its experience up to that time with its physical, biological, and social environments. This is an experience with habitat, climate, nutrition, excretion, physical exercise, work, play, leisure, social activity, rest, and disease. Out of the development and training derived from these experiences comes whatever degree of strength, endurance, vigor, or resistance to fatigue the individual may possess. What is excessive for the resistance of one may be within the normal limits of another. The physical exercise that enters into the training program of a varsity football team would be excessive for a freshman squad. The physical exercise of the high-school athlete would be even more excessive for a child of the elementary school age. The limits of normal physical exercise beyond which the activity becomes excessive are at different and ascending levels in the periods of pre-adolescent childhood, adolescent youth, and post-adolescent maturity. The levels drop with later maturity—after thirty perhaps—middle age, and old age.

Excess in physical exercise depends also on the nature and amount of the activity that is involved. Excess may be a product of mechanical work, or of speed of repeated movements, infrequency or insufficiency of rest periods, or it may be a product of the total duration of the activity. Finally, excess leading to fatigue and even exhaustion arrives earlier when the exercise is unattractive and monotonous.

Fatigue.—Excess of physical exercise ordinarily brings first a desire for rest. This feeling of reluctance to continue the muscular activity is probably due to stimulations of sensory end organs associated with the contracting muscles. A continuation of the excessive activity, despite the feeling of being tired, leads to more urgent feeling of fatigue. A still further excess ends in a complete inability of the muscles to continue their contractions un-

less they are first rested. Observation and experiment teach that the fatigue of physical exercise may be local or general, acute or chronic, normal or injurious.

Local fatigue.—A great deal of experimental work has been done with the fatigue of single muscles and of small groups of muscles. The muscles of cold-blooded and of warm-blooded animals have been used for such researches. The leg muscle (gastrocnemius) of the frog has furnished a rich literature on the physiology of muscular contraction. The little muscle in the human hand that pulls the index finger away from the second finger and toward the thumb (the abductor indicis) has been a source of similar information.[1] Angelo Mosso, a great Italian physiologist, and later Warren P. Lombard, an American physiologist, experimented with small groups of muscles that flex the fingers. In these researches the muscles were sometimes contracted voluntarily and sometimes they were made to contract by stimulating them with electrical currents. Whatever the method of stimulation, whether voluntary or electric, the phenomena of tiring and of fatigue and of exhaustion are essentially the same, regardless of the animal or the method of stimulation. The experimental fatigue produced in the laboratory enables the student to analyze and better understand some of the phenomena that are commonly noted in the physical exercise of everyday life—in work, play, sports, and athletics.

If a single muscle is made to lift a heavy weight a number of times with only a short interval of rest between lifts, the muscle soon tires and eventually becomes unable to lift the weight. After a few seconds of rest, the muscle is again able to lift the weight only to tire again more rapidly than the first time if the work is continued. Thus, with a heavy weight to lift, and a rapid rate of contraction, fatigue soon compels the muscle to stop work. A short rest partially restores the power of contraction, a long rest completely restores it. These phenomena appear with appropriate electrical stimulations of the muscle-nerve preparation of the frog (the gastrocnemius muscle and sciatic nerve of the frog); or with the electrical stimulation of the human abductor indicis;

[1] Thomas A. Storey, *Studies in Voluntary Muscular Contraction,* Dissertation, 1902, Stanford Library; "Influence of Fatigue on the Speed of Voluntary Contraction of Human Muscle," *American Journal of Physiology,* Vol. VIII, No. 4, January 1, 1903, p. 355.

or with the natural voluntary stimulation of any human muscle or group of human muscles. The evidence of tiring, of fatigue, and finally of exhaustion under various experimental conditions may be recorded by ingenious laboratory devices and then carefully studied. In addition, the muscles and nerves of lower organisms may be examined for chemical and microscopic evidence of fatigue. Finally, the chemical intake and the chemical outgo of resting, active, or fatigued muscles may be analyzed and measured with precision so that much has been learned concerning the chemistry of muscular contraction.[1]

Because of extensive physiological research along these various lines we know that muscle contraction is accompanied by a dissociation (breaking down) of carbon compounds in the muscle-cell. The carbon compound of importance in muscle contraction is known variously as blood-sugar, glucose, muscle starch, or muscle glycogen. The dissociation of muscle carbohydrate during muscle contraction diminishes the amount of glycogen in the muscle and leads to the formation of lactic acid, carbon dioxide, water, and heat. We find, too, that muscle exercise leading to fatigue is accompanied by chemical changes in the bodies of the motor nerve-cells and in the motor end-plates in which the motor nerve endings terminate as the muscle fibers.

We have ample evidence from these various sources that the phenomena of local muscular fatigue appear as soon as the supply of chemicals essential to the production of muscle contraction are used up faster than they are replaced from the blood and lymph that surround the muscle fibers. The depletion of chemicals essential to contraction may be a depletion of chemical compounds in the muscle fiber, its motor end-plate, or in its motor nerve.

After a short rest—a few seconds may be enough—the chemical wastes and excretions of muscle contraction may be removed by the lymph and blood, and a new supply of essential chemical compounds may be made immediately available to the fatigued muscle. It then is once more able to contract, although its full power of repeated contraction will not be restored unless the period of rest is long enough for the muscle-cells to replace their chemical expenditures completely.

We have noted that the chemical depletion that constitutes fatigue of muscles is largely a depletion of muscle carbohydrate.

[1] See chapters on nutrition, excretion, and physical exercise.

It must not be forgotten, however, that muscle fatigue may be due in some part at least to structural (i.e., protein) wear and tear. We have experimental evidence that muscular activity pushed repeatedly to the point of exhaustion in the single muscle is carried on at the expense of the protein structure of the muscle-cells. The continued work of an exhausted muscle thus subjects it to a structural strain that is repaired more slowly and perhaps less efficiently than the replacement of the muscle glycogen expended in the fatiguing exercise.

General fatigue of excessive physical exercise.—So far, we have considered some of the effects of excessive physical exercise upon the exercised muscle (and its motor nerves). As long as the individual is exercising only a few small groups of muscles, or as long as his exercise is moderate, the effects are confined to the muscle groups that are active. But with a considerable number of muscles participating, or with the vigorous exercise of big muscle groups, there is necessarily involved also an increase in the activity of the muscles of the heart, the circulation, and of the lungs. Because of the demands of vigorous exercise, more oxygen and more muscle carbohydrate (glycogen or glucose) must be supplied the depleted muscle-cells, and the excess of lactic acid, carbon dioxide, and heat produced by the fatiguing contractions must be removed from the vicinity of the contracting cells and expelled from the body. The muscle-cell (muscle fiber) excretions produced during contractions contain poisonous compounds. It has long been known that the transfusion of blood from a fatigued animal to a rested animal produces the symptoms of fatigue in the rested animal. It has been shown, too, that the transfusion of blood from a rested animal to a fatigued animal immediately relieves the fatigued animal of the symptoms of fatigue. Concisely these are the reasons for the rapid heart rate, the higher blood pressure, the rapid respiration, and the increased perspiration of vigorous general physical exercise.

General fatigue is thus a sum total of fatigue effects from the participating individual voluntary muscles, the muscles of the heart and circulation (arterial walls principally), the muscles of respiration, and the neurones associated with them. But it is important to remember in considering muscular fatigue that under normal conditions of life fatigue is never purely muscular. It is always partly fatigue of spinal motor nerves and partly of motor

nerves of the central nervous system. It may involve fatigue of the autonomic nervous system. The participation and possible fatigue of other organs and systems must be recognized, such as (1) the liver which, among other things, (*a*) manufactures the glycogen that gives the muscles dynamic energy for contraction, and (*b*) neutralizes various poisonous chemicals produced by voluntary muscle contractions; (2) the pancreas, and its manufacture of insulin that is so essential to the chemistry of muscular contractions; (3) the bone marrow, from which come the red blood cells that carry oxygen to the muscle fibers, without which they cannot continue contracting, and carry carbon dioxide away from the contracting muscles; (4) the suprarenal glands, whose secretion, epinephrin, participates in producing the increase in blood pressure that accompanies muscular activity. This list of integrating organs and functions could be extended considerably, but enough has been noted to establish the fact that there is no such thing as muscular fatigue independent of all other sorts of fatigue.

Normal muscular fatigue is the ordinary tire of muscles that does not lead to exhaustion and is easily relieved by rest through inactivity. One rests his legs long before he has walked his limit and is soon ready to walk some more. Normal local muscular fatigue is a part of the requirement for the normal nutrition, growth, and development of individual muscles. Normal general muscle fatigue is a fatigue of the general voluntary musculature. Such fatigue stimulates general nutrition, growth, and development. It is an important factor in the relation of physical exercise and play to constructive hygiene.

Acute muscular fatigue.—An excessive exercise of a small group of muscles in a short period of time rapidly uses the available chemical sources of energy in the muscle and soon leads to exhaustion. This is known as acute muscular fatigue. The acutely exhausted muscles require immediate rest in order that their chemical losses may be replenished.

If a large group of muscles or a number of smaller groups are vigorously exercised for a sufficiently long period of time, acute general fatigue will occur.

The window cleaner whose accident placed him for a few minutes hanging by his finger tips from the window ledge lost his life because of the acute local fatigue of the small groups of muscles that controlled the flexion of his fingers.

The fisherman who casts his fly may experience acute local fatigue of hand, arm, and shoulder early in the season before he is trained into condition, or experience acute general fatigue if he hurriedly climbs a mountain trail on the way to the brook of his choice.

The acute fatigue of excessive physical exercise.—We have noted above and in other chapters[1] that the chemical events of physical exercise include an increased production of carbon dioxide, heat, and water, and an immediate demand for more oxygen and more muscle carbohydrate (glycogen), and that under these circumstances there must be an increased heart rate bringing more oxygen and more blood sugar to the active muscle-cells and carrying more carbon dioxide and more water away from them, and that, in consequence, there must be an increase in the rate of breathing for the more rapid removal of carbon dioxide and for the capture of an ample supply of oxygen from the air. And there must be an increase in perspiration (sweating), which along with the more rapid ventilation of the lungs through increased respiration serves as a cooling process, preventing or obstructing overheating from physical exercise.

For these reasons the rate of the heart beat, the pressure of the capillaries of the blood stream, the rate of the flow of the blood through the active muscles, the respiratory movements of the lungs, and the production of sweat are enormously increased when one engages in vigorous physical exercise. These increases throw a heavy obligation on the heart muscles and on the respiratory muscles. Under the circumstances, vigorous physical exercise inevitably leads to breathlessness. The muscles of the heart and those of the lungs soon tire. Their length of endurance depends on their training. With the normal individual, breathlessness arising during physical exercise is a symptom of heart tire and lung tire. It is a symptom of acute fatigue.

The excessive demands of a hundred-yard dash may lead to acute heart and lung muscle tire and consequent breathlessness and collapse within a few seconds. The rapidity and degree of this acute fatigue of the sprinter depends on his condition and his training. He is "out of breath," exhausted, and collapses as soon as his heart and lung muscles are unable to work fast enough to remove the excess of carbon dioxide and maintain the necessary supply of oxygen in his blood stream.

[1] See chapters on excretion and physical exercise.

Acute fatigue and exhaustion arrive rapidly in some individuals during physical exercise because of an inadequate supply of blood-sugar. Marathon runners with a low percentage of blood-sugar are more easily exhausted than their competitors with a higher percentage. Distance men who are judiciously fed with sugar prior to their races do not exhibit the extreme degree of acute fatigue that has been recorded for runners with a low percentage of glucose.

Signs of acute fatigue are inevitably present in every form of vigorous or violent physical exercise. These signs vary objectively from rapid breathing to difficult breathing, breathlessness, extreme pallor, the distorted features of the effort of agony, collapse, and unconsciousness.

Urinary examinations after acute fatigue commonly show the presence of albumen, blood cells, kidney cells, and sometimes sugar. The findings indicate a rather profound disturbance in the chemistry of the active organs including the kidneys. Normally, all these findings disappear after rest.

It is probable that in the majority of cases acute fatigue serves a protective purpose for the normal individual. His breathlessness and physical inability to continue his vigorous exercise ordinarily save his laboring organs from further excessive demands. The dangers consequent on the physical stresses that lead to acute fatigue are serious for those individuals with defective motor organs. It is probably dangerous to physical health to ignore the signals of acute fatigue and continue to force the voluntary muscles to excessive activity. The high-school athlete who wins all the events on the track from the hundred-yard dash to the mile run in a single field day may suffer organic injuries from which he never completely recovers, though their presence or permanence may not be noted until advancing years reveal them.

It must be admitted that the drive of a compelling purpose may so powerfully influence a given individual despite the warnings of acute fatigue as to force him to an extreme of continuously excessive physical effort resulting in his irreparable health injury and even in his death. The story of Phidippides may be a myth. But he who ran from the plain of Marathon to the Agora of Athens after the battle might well have delivered his message and his life at the feet of his anxious people. The demands of a great calamity—shipwreck, fire, flood, volcanic eruption, invasion, epi-

demic—have been known to call for continuous service that has led to extremes of physical activity, the acute fatigue of which has taken health and even the lives of those who served. But these sacrifices are probably products of various combined influences. Along with these excesses of physical activity there were also such accompanying adversities as exposure, loss of rest, inadequate nutrition, disease, and fear.

The loyalties or athletic ambitions of high-school boys and girls and of college students are known on occasion to lead them to excesses of physical exercise in athletic competition against which the protective influence of acute fatigue has been too slow in its final control over the activity. When the individual is prepared for his contest by a competent coach who thinks more of the player than of the score, there is likely to be a safeguarding medical supervision, and a safeguarded training and conditioning, and a safeguarded competition. But, when the school spirit or group spirit becomes intense in the absence of mature experienced instruction, the competition sometimes has no protective limitation for the individual competitor. His enthusiasm may be permitted to drive him on far beyond the limit established by ordinary acute fatigue. There are, therefore, health hazards in unsupervised scholastic or collegiate athletics. These same hazards are even greater in unsupervised community recreations and athletic club programs.

The prevention of acute fatigue from excessive physical exercise.—The safeguards of the individual from excess in his physical exercise are secured through (*a*) advice as to organic condition based on scientific health examinations given by dependable experienced physicians prior to the beginning of the program of activity, and at intervals thereafter (periodic medical examinations); (*b*) a regular program of physical recreation, games, sports, or athletics (i.e., a rational training) that does not produce undesirable symptoms of fatigue or expose the individual to excesses of effort; (*c*) a wise respect for the importance of rest; and (*d*) a reasonable program of individual hygiene (nutrition, excretion, work, play, rest, and avoidance of the causes of disease).

The individual who plans to go into physical competitions cannot wisely omit securing the advice of a competent physician and the guidance of a competent coach.

Accidents of excessive effort.—Muscles that are given an excessive amount of exercise differing from their customary activities become sore and tender. They may be painful and contract with difficulty. A vigorous set of tennis after a long absence from the game, a mile race with no preliminary preparation, a brisk walk with legs that are accustomed only to the clutch and accelerator, are samples of excessive physical exercise that lead to sore muscles.

Structural injuries caused by excessive physical exercise might be described as "effort injuries." The powerful contraction of a muscle as a part of an extraordinary effort sometimes tears a portion of the structure of the muscle, breaks its tendon, or pulls out the bony insertion of the tendon. A torn muscle, pulled tendon, "shin splints," or "Charley horse" are usually results of excessive efforts without appropriate preliminary training and conditioning.

Sometimes the power of the unguarded contraction is sufficient to break the bone to which the muscle is attached. The patella (knee pan) is occasionally fractured by a sudden uncontrolled contraction of the great anterior mass of thigh muscles in the tendon of which the patella is located. These sudden powerful contractions sometimes cause strains of the ligaments about a joint, as in a "sprained" ankle, or they may cause a dislocation of the bones that form a joint, as in the shoulder. However, joint strains and dislocations are commonly caused by adverse outside mechanical influences in combination with muscular effort.

Rupture of blood vessels caused by effort.—The increase in blood pressure that always accompanies the muscular effort of normal people is ordinarily well within the limits of the strength of the walls of the arteries and small blood vessels, especially in younger people. But if there are weak points or regions in the walls of these vessels, a great increase in the pressure of the blood stream within them may rupture the vessel and cause hemorrhage. Excessive effort made by people whose blood vessels are weak because of disease (e.g., syphilis), age, or other degenerative influence is a well-recognized cause of cerebral hemorrhage and paralysis (apoplexy or shock).

Excessive effort and the heart.—Heredity and experience ordinarily furnish the individual with a normal heart and a normal system of blood vessels that will meet any of the ordinary demands and, within limitations, even the extraordinary demands that his

activities may make upon them. But not all hearts are normal. Nor are all arteries, capillaries, and veins normal. One may have a heritage that equips him with a defective heart or blood vessel; he may acquire such defects congenitally; or later disease may damage the muscles or valves of his heart or the walls of his arteries. Under these circumstances an excessive blood pressure brings a hazard to the heart or to the vessels. Effort always produces increased blood pressure. Thus, excessive effort and especially repeated excessive effort is often a cause of injury to individuals with vulnerable hearts or with vulnerable arterial walls. Disability and death are too commonly the penalties paid for subjecting weak heart muscles (flabby from disuse or degenerated by disease), damaged heart valves, or frail arterial walls to the hazards of excessive physical exercise. These hazards are more common in the lives of older men.

The relation of the heart and circulation to the physical exercise of everyday life and to the requirements that accompany every muscular effort in the day's program is one of the convincing arguments that establish the demanding importance of annual or semi-annual scientific health examinations and prove the wisdom of a daily balanced program of health habits that include interesting, appropriately vigorous general physical exercise.

The periodic inquisitive health examination enables one to more successfully safeguard himself from the hazards of the defects of the heart or circulatory apparatus that may be found. The daily health-habit program should give him muscles of locomotion, heart muscles, and muscles of circulation trained and conditioned to meet within reasonable limitations the effort emergencies of his daily life.

Hernia (or rupture) of the abdominal wall is another fairly common health injury caused by excessive effort. There are various points or areas in the abdominal wall that are naturally relatively easily ruptured. These areas of relative weakness are much more vulnerable in some persons than in others. When one holds his breath and strains in muscular effort, as in lifting or pushing a heavy load, the powerful muscles of the abdominal wall contract and produce a correspondingly powerful pressure on the contents of the abdomen. This intra-abdominal pressure is exerted in every direction against the surrounding wall of the abdominal cavity. If the pressure at any point is greater than the resistance of the wall

at that point, the wall breaks. This "break" is known as a "rupture" or "hernia."

The commonest hernias are the inguinal hernias. They occur because the canal leading from the abdomen to the inguinal region is a point or area that is naturally relatively weak. This canal (the inguinal canal) contains arteries, veins, nerves, and other important organs. The entrance to the canal and its own walls are sometimes too weak to resist the pressure from within the abdomen caused by excessive effort. Some of the contents of the abdomen may then be forced into the enlarged inguinal canal and eventually through the canal. Loops of the small intestine, parts of the mesentery, or other organs or contents of the abdomen are sometimes brought down with the hernia. The small intestine may become kinked or twisted and its canal closed, or blood vessels similarly may become closed. Such a closure of the intestinal canal or of a blood vessel of the mesentery constitutes a "strangulated hernia." Strangulation may occur with any hernia. The end result of strangulated hernia is either a successful surgical operation or death.

The possibility of an unsuspected hernia is another fact that establishes the importance of periodic health examinations as an essential part of a rational health-habit program.

The hazards of unsuspected incompetent hearts or of fragile arteries or the beginnings of hernias are samples of reasons for the very careful health examination of prospective athletes and of all athletes before and during all seasons of training and competition.

Effects of excessive physical exercise on longevity.—Various investigators have reported on the effects of heavy physical exercise upon longevity. Contradictory conclusions have been reached concerning the influence of college athletics upon the duration of the life of the athlete.[1]

Raymond Pearl has made a painstaking examination of pertinent items in the extensive mortality statistics of England[2] with the following conclusion:

"After roughly age forty to forty-five it appears that a man shortens his life by definite amounts in proportion as he performs physically heavy labor."

[1] Louis I. Dublin, "Longevity of College Athletes," *Harper's Monthly Magazine,* July, 1928.

[2] Raymond Pearl, *Studies in Human Biology* (Williams & Wilkins Company, 1924), p. 352.

CHAPTER XXV

HEALTH HAZARDS OF PLAY: DEPRIVATIONS, DEFICIENCIES, AND OTHER HEALTH HAZARDS OF PLAY AND THEIR PREVENTION

Definition of play.—Play is experience with satisfactions. This experience may be an anticipation, a realization, or a memory of satisfactions. Ordinarily play is a sociable experience in which voluntary motor activity (physical exercise) is prominent. But play may be passive. It may be solitary. Fantasy, day dreams, and air castles are different names for unsociable passive play. One may secure his play, in part, watching the active play of others. Absorbing work, mental or physical, is play. The word "play" leads one to think first of the play of children. But it includes, too, the sports and athletics of youth; the recreations, entertainments, and leisure-time occupations of youth and maturity; and the absorbing satisfactions of honest work or of vicious delinquency.

Play is characteristic of child life. Animals that are born mature have little or no play that we can recognize. The normal play life of human infancy, childhood, and youth is a life of physical exercise and mental exercise (voluntary motor activity) combined for the purpose of satisfying the requirements and urges of the tropic mind (possibly?), the reflex mind (unconditioned and conditioned), the instinct mind, and the intelligent mind of the slowly maturing human being. The motor life of the mind and the soma (or body) is essential to the growth and development of the mind and the body. Normal growth and normal development are significant of normal health. The possibilities of normal health (mental and somatic) are limited or destroyed by deficiencies or deprivations of play during the period of immaturity.

Mental health, physical health, and social health depend in large part on the quality of the play life of the earlier age periods.

If the influences of conditioning stimuli (imitation, suggestion, authority, and satisfaction) in the life of the child are such as to build social habits, attitudes, and sentiments, the product will be a healthy mind, assuming a basic normal mental heritage to start with.

Deprivation of play.—There is probably no such thing as a normal child utterly devoid of play. The drive of physical-chemical stimuli, of instinct hungers, of conditioning stimuli, and of mature intelligence must compel some form or degree of physical and mental play experience.

Deficiency of play.—But there are and always have been a great many men and women whose personalities display qualities of poor mental health or of mental disease that are results of deficiencies of play life.

It is not possible in the present stage of our knowledge to point out specific deficiencies of play and the specific injuries to mental, social, or somatic health caused by those deficiencies. But there is a good deal of collected evidence, in the records of abnormal psychology and of psychiatry, to the effect that the mental diseases of maturity are in large part products of deficient or defective play life during the formative periods of infancy, childhood, and youth. We recognize the unsociable adult personality characteristic of him who was an only child. The youngster who persistently plays alone is rather more likely to be a neurotic when maturity arrives. The deficiencies and defects in the social behaviors of adults and playmates become conditioning stimuli that affect behavior of the infant or child through imitation, suggestion, obedience, and habit.

The health hazards of defective play.—The initial desires of the individual child are for the satisfactions of primitive urges. His conduct tends to follow inherent patterns of behavior. The first movements of the infant are inevitable responses to (i.e., satisfactions of) environmental stimuli. The play of children, therefore, has a tendency to exhibit instinct motivations and their associated emotional states. Unless there is some sort of effective control (such as, for example, wholesome suggestion, acceptable direction, or ready obedience), selfishness, envy, and jealousy will appear. Unhappiness, fear, pugnacity, quarreling, may destroy the wholesome mental hygiene of play. The tyrannies, cruelties, tearfulness, and depressions of the unguarded play life of some children leave indelible records that characterize the anti-social personalities of adult life.

When the play of the child includes an excess of petting and coddling, there may be a resulting nervousness with habits of irritability, tantrums, moodiness, and sullenness.

Such children on reaching adolescence, or later on entering the

high school or college, have difficulty in adjusting themselves to social standards. They are likely to become neurotics.

Not the least important danger of unguarded play is the hazard of sex perversion and precocious sex experience.

The play of youth and of maturity, whether it be vigorous motor satisfaction, appropriate physical recreation, intelligent mental enjoyment, superficial entertainment, sensuous emotionalism, or vicious selfishness, is largely a product of the play of the preceding childhood years.

Defenses against the health hazards of play. — Physical exercise and play are so intimately related and so much the same that their health benefits and health hazards are basically inseparable. The advantage of describing them separately may easily blur the fact that organically and functionally neither could exist without the other. Our description of defenses against organic injuries caused by physical exercise stated in a preceding chapter may be reviewed here as an important part of our discussion of our defenses against the health hazards of play. And the following discussion of defenses against injuries of mental health caused by play may be considered as applying to the hazards of physical exercise as well.

The protection of the mental health-values of play during the period of dependent immaturity can come only from the adults on whom the helpless infant and almost equally helpless child depend. The responsibility for the social, mental, and somatic hygiene of childhood's play thus rests mostly on parents, teachers, and community leaders. Adult example is a model that patterns child behavior. If father or mother is irritable, cross, arbitrary, or cruel, the play life of the child will contain irritations that become permanent characteristics unless counteracted very early by some potent counter-defense.

Parents, above all others, are given opportunity to safeguard the mental health of children, particularly their own children. The hazards of play stand or fall largely in response to parental example and parental protection. The example and methods of the teacher are a close second to those of the parent. Under the influence of a tactful, resourceful, mature understanding of the possibilities and hazards of play, children may be led away from the emotional excesses of intolerance, anger, rage, or hate; sexual precocities or perversions; the injustices of selfishness, jealousy, envy,

or cruelty; the sufferings of fear and terror; the disappointments of defeats and hard knocks; the unsocial refuge of solitary play, day-dreaming, resentful brooding, grievance, and grudge-nursing; failure to adjust or faulty ways of meeting the difficulties that must arise in the play of normal children. Under an unobstrusive guidance that seems to come from within the child rather than from the parent or teacher to the child, there is a probability of successful defense against the mental health hazards of play. The normal play of children is vigorous and aggressive. It is concerned with the realities of environment and life. It serves its greatest purpose when it helps train the child for life through habit and attitude-forming experiences with wholesome satisfactions, healthful happinesses, and successful social adjustments.

The defense of youth and maturity against the health hazards of their play life begins at birth. The self-control, the power to settle a mental conflict, the capacity to find and enjoy satisfactions that are physically, mentally, and socially healthful, are qualities of mind that are essential to the successful defense against the health hazards of adult play, and are qualities that are formed out of the preceding experiences of infancy and childhood. The self-defense of the adult will be more easily maintained against the health-damaging temptations of sedentary leisure, emotionally excessive entertainment, or vicious satisfactions if his childhood play life was wisely guided and protected.

The content of adult life includes a great variety of experiences with satisfactions that, in accord with our definition, belong to play. A very considerable number of these satisfactions are experiences that may jeopardize somatic, mental, and social health. A defense against such hazards consists in omitting the experiences that bring them on or in regulating those that must be met. Among the factors of adult play life that damage mental and bodily health are late hours and inadequate rest, gourmandizing, high-pressure social excitements, alcoholism, excessive use of tobacco, promiscuous petting, prostitution, the anxieties of betting and gambling.

CHAPTER XXVI

MECHANICAL CAUSES OF DISEASE: MECHANICAL INJURIES, ACCIDENTS, AND OTHER MECHANICAL CAUSES OF DISEASE

The mechanical causes of disease.—Those influences that injure health or destroy life through pressure are the mechanical causes of disease. Structural and functional damage may follow pressures applied to parts of the body because of bad posture, tight garments, clothing that rubs, occupational habits that emphasize bad bodily mechanics, and contact with pressures from the external environment. Thus the mechanical causes of disease may be present in the internal environment, as in the pressures of bad postures, muscular effort that "pulls" a tendon or causes "Charley horse"[1] or precipitates apoplexy, or in the external environment, as in the pressures of tight shoes, a fall from a stepladder or a horse, the impingement of a speeding bullet, a collision with an auto, a bad tackle in football, or the force of a cyclone.

Damaging pressures may be slow in their causation of injury, as in the production of a corn, a fallen arch, round shoulders, some sorts of backache, and the irritations that develop cancer. Other pressures are sudden, as in a gunshot, a fall, or the stab of a dagger. There are, then, chronic and acute pressure injuries. Pressures produce structural damages and functional disturbances through such effects as (*a*) bruises, contusions, lacerations, tearings, sprains, and fractures; (*b*) concussion; (*c*) puncture; (*d*) section; (*e*) compression; and (*f*) distention.

Mechanical injuries due to pressures from the external environment are so very common and so frequently serious that they logically deserve special consideration here. Our discussion will be directed mainly to mechanical damages from the outside. The open wounds that so frequently result from mechanical injuries often become avenues of bacterial infection so that abscesses and other exhibitions of septic poisoning often complicate injuries of mechanical origin. In addition, mechanical injuries are very frequently associated with disasters that cause so much fear and such

[1] R. Tait McKenzie, *Exercise in Education and Medicine* (W. B. Saunders Company, 1923), p. 31.

great terror that they lead to mental and nervous diseases. Mental or nervous traumatisms, though not structurally visible even under the microscope, are as real as the bruises of an automobile collision, a train wreck, or a burglar's slug.

We have various sources of information that establish the importance of the external mechanical causes of disease. The greatest of these sources is the Bureau of the Census in the United States Government Department of Commerce. This bureau records the number of deaths from various mechanical causes reported each year from the area of registration in the United States.[1]

The non-fatal health injuries of mechanical origin are far more numerous than the fatal injuries. Information concerning the occurrence, nature, and importance of non-fatal injuries, as well as fatal injuries of mechanical origin, may be secured from (*a*) the records of those states in which employers' liability and workmen's compensation acts are in operation; (*b*) reports of insurance companies; (*c*) publications of industrial organizations; (*d*) state highway commissions; (*e*) national automobile associations; and (*f*) various national safety organizations.

Mechanical injuries play such an overwhelmingly prominent part in accidents from all sources that it is approximately accurate to regard accident statistics and facts as representative largely of the statistics and facts relative to mechanical agents that injure health. For purposes of our discussion here we will consider the prominence of mechanical injuries in (*a*) home accidents; (*b*) school accidents; (*c*) industrial accidents; (*d*) public motor-vehicle accidents; and (*e*) public accidents, not motor-vehicular.

Home accidents.—Our information concerning accidents at home is incomplete. Many such accidents are not reported. The facts that have been reported for 1934 are therefore significant of a greater, probably much greater, incidence than they describe.

The National Safety Council reports 34,500 deaths from home accidents in 1934. These accidents include, in their order of frequency, falls; burns, scalds, and explosions; asphyxiation and suffocation; poisons; cuts and scratches; and "other home accidents."

[1] Much of the information presented here is based on the *Mortality Statistics, 1932,* Department of Commerce, Bureau of the Census, and on publications issued by the National Safety Council, Chicago (*Accident Facts, 1935*).

Almost 50 per cent of the 34,500 deaths from home accidents were due to falls. Five-sevenths of the deaths from falls were of persons sixty-five years of age or older.

Accidents to school children.—Data analyzed and reported by the National Safety Council show that "nearly two-thirds of all school child accidents occur outside the school hours and off the school property. Only one-tenth of the total occur on the way to or from school."[1]

Industrial accidents.—Accidental injuries of persons while they are gainfully employed are classified as "industrial accidents." There are at present no accurate complete records of industrial accidents. The National Safety Council reports the estimated number of fatal industrial accidents in 1934 at 16,000, with 60,000 permanent disabilities, and 1,300,000 other injuries.

Public motor-vehicle accidents.—Motor vehicles killed 36,000, permanently disabled 100,000, and injured another million people in 1934. These accidents cost approximately $800,000,000, not counting the property damage involved. All important types of fatal motor-vehicle accidents showed increases in 1934. The motor-vehicle deaths increased 15 per cent from 1933 to 1934, whereas population advanced only 1 per cent in the same period.

The death-rates from automobile accidents in 1934 are highest in the Pacific Coast and Rocky Mountain states, lowest in the Mississippi Valley states, and intermediate in the Atlantic and New England states. In recent years the rural death-rate from automobiles has exceeded that of the city death-rate. Sixty-four per cent of the automobile deaths in 1934 occurred in rural districts.

About one-third of the rural death-rate from automobiles involved pedestrians, while 67 per cent of the fatal automobile accidents in cities involved collisions with pedestrians. Approximately 50 per cent of the total number of deaths (36,000) from automobile accidents are pedestrian deaths (16,200).

Children of four years and under constituted 77 per cent of the pedestrian fatalities, although this death-rate has been decreased from 13.9 in 1929 to 9.6 in 1934.

Deaths at grade crossings are estimated at 1,450 for 1934. Accidents in which two motor vehicles are involved have increased 17 per cent from 1933 to 1934.

[1] National Safety Council, *Accident Facts, 1935,* p. 44.

The greatest hazard of automobile accidents to pedestrians seems to be in crossing streets at intersections having no signal and in crossing the street between intersections. The next most hazardous exposure to automobile injury is while playing on the street. A survey of the accidents shows that the responsibility of the drivers can be traced to the following: (*a*) excessive speed; (*b*) driving off roadway; (*c*) did not have right of way; (*d*) driving on wrong side of road; (*e*) cutting in; (*f*) failure to signal; (*g*) passing on curve or hill; (*h*) passing standing street car; (*i*) failure to stop at signal; (*j*) driving through safety zone. Other conditions for which the drivers were not directly responsible include: (*a*) defective condition of the vehicle (in most cases, the brakes); (*b*) bad roads; and (*c*) bad weather conditions.

Of the fatal motor-vehicle accidents of 1934, 6 per cent of the drivers, and 7 or 8 per cent of the pedestrians, were reported "intoxicated" or "had been drinking," an increase over the 1933 figures of 5 per cent and 6 per cent, respectively.

Public accidents, not motor-vehicular.—The accident facts for 1934 published by the National Safety Council record that the annual number of individuals killed in public places in accidents in which there was no motor vehicle is approximately 17,500. This figure shows a distinct decrease from the number, 21,000, for the year 1928.

Information concerning the non-fatal accidents of this sort is difficult to secure and is, therefore, incomplete. It is estimated that there were approximately 2,500,000 non-fatal injuries of this sort in the United States in 1929.

The most important of the several sorts of public accidents other than those of motor vehicles, in their order of frequency, are (1) fatal (*a*) drowning, (*b*) railroad accidents (not with motor vehicle), and (*c*) electric car (not with motor vehicle); (2) non-fatal (*a*) electric car (not with motor vehicle), (*b*) other street accidents, (*c*) vehicles other than electric car, but not with motor vehicle, (*d*) buildings and structures, and (*e*) firearms.

Summary of accidental deaths from all causes.[1]—From 1922 to 1934 the total number of accidental deaths increased from 76,420 to 101,000. This increase is all among adults, the total

[1] National Safety Council, *Accident Facts,* 1935.

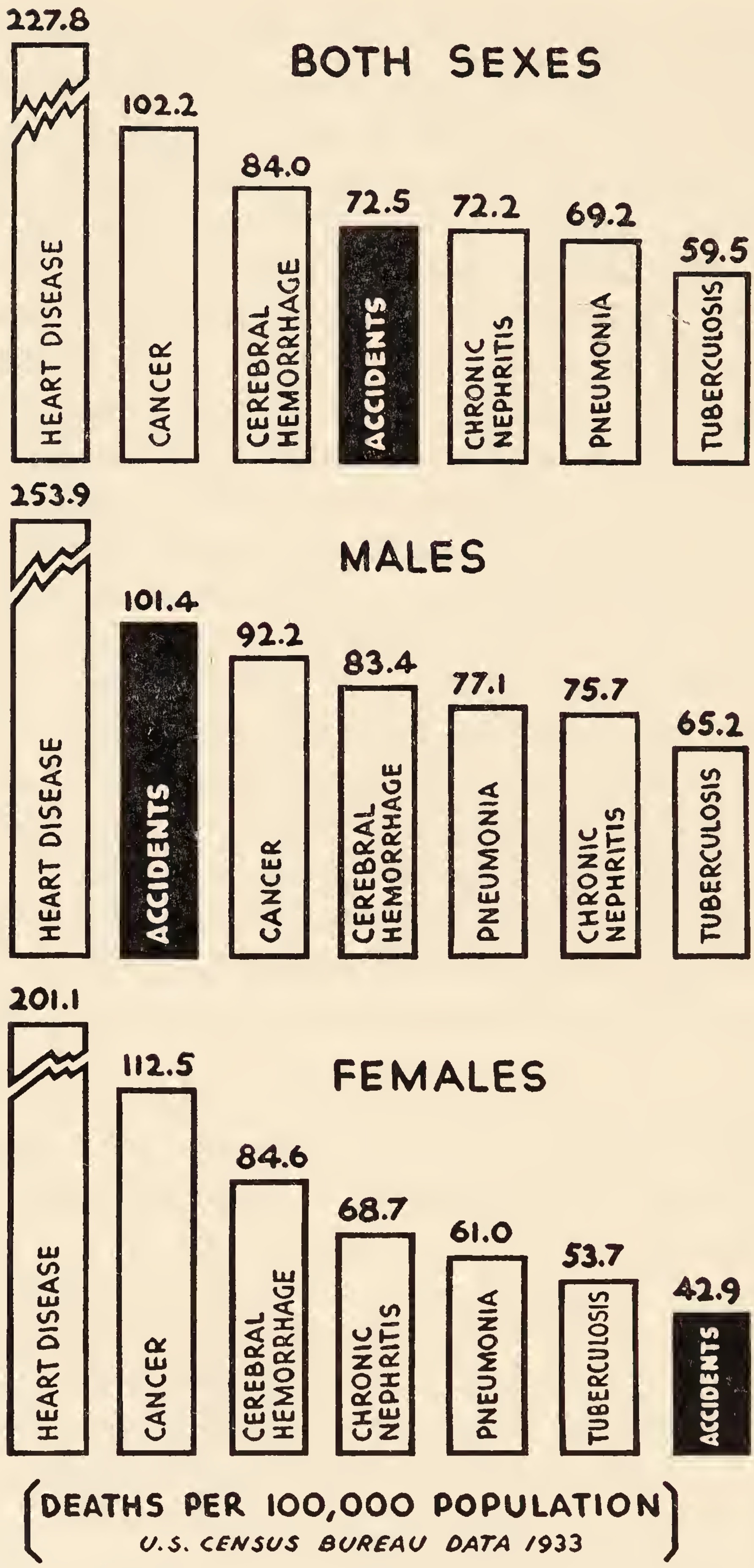


FIG. 54.—Chart showing the seven most important causes of death, taken from *Accident Facts, 1935,* National Safety Council, p. 7.

accidental deaths for children up to fourteen years of age having been reduced during this same period from 18,576 to 15,400.

The most important sources of accidental mechanical injury are first, the automobile; second, falls; and third, drowning.

There were more than twice as many accidental fatalities at home during 1934 as there were in the industries, and almost as many as in motor-vehicle accidents.

Dust as a mechanical cause of disease.—Atmospheric dust is requisite for the formation of rain drops. Such dust is a normal and necessary constituent of the air that surrounds the earth.

Some dust contains pathogenic organisms. This may be true of street dust or of house dust. Such dust carries micro-organisms that cause inflammation with boils or with abscess formation if it is permitted to enter open wounds. It may be a source of inflammation in the nose or throat or lungs if inhaled.

Some dusts are poisonous. Such dusts will be discussed in connection with the chemical causes of disease.

There are other dusts that cause injury mechanically in case they are present in sufficiently large amounts or are breathed for long periods of time.

Metallic dusts from such metals as iron and steel have sharp angular projections that easily irritate the mucous membranes. Other similarly irritating dusts arise from granite. The dust from silica is well known for its harmful effects but the evidence now seems to prove that its influence is chemical rather than mechanical. This dust is a serious hazard in (1) mining or quarrying or otherwise working with quartz, quartzite, sandstone, grit stone, and cheet; (2) foundries; (3) potteries; and (4) tin mines.

Dusts from coal, chalk, cement, marble, and plaster of Paris are mechanically injurious but less irritating than the dusts of iron, steel, and granite. The irritating effects of these dusts are so well known as to have special names given to the diseases they produce. Thus, we have for dust disease in general the name pneumoconiosis; for stone dust, siderosis or chalicosis; for coal dust, anthracosis; and for dust of vegetable fiber, byssinosis.

CHAPTER XXVII

PHYSICAL AGENTS THAT ARE INJURIOUS TO THE HEALTH

The physical agents that injure health.—These agents may be classified as follows: (1) Atmospheric pressure: (*a*) diminished pressure, (*b*) excessive pressure; (2) temperature: (*a*) low temperature, (*b*) high temperature; (3) light: (*a*) insufficient light, (*b*) excessive light; (4) the X-ray; (5) radium; (6) electricity: (*a*) lightning, (*b*) electricity other than lightning.

Variations in *atmospheric pressure* are not of much importance in the affairs of the ordinary individual. Those who climb high mountains or go to the high mountains for vacations, or make balloon ascensions to great heights may suffer with giddiness, rapid breathing, rapid heart rate, nose-bleed, weakness, or exhaustion. These are effects of low atmospheric pressure. They are symptoms due to an insufficient supply of oxygen in the blood. On the other hand, men that work in caissons, building tunnels under rivers, for instance, suffer from the effects of high air pressure. The laborer returning from such work to normal air pressure too rapidly suffers excruciating pain, and, in some cases, death. He is said to have "benders" or "caisson disease." The excessive air pressure forces the blood to take on an increased amount of oxygen, nitrogen, and carbon dioxide gas. When the excessive pressure is reduced suddenly, it seems that the blood is unable to get rid of its increased content of nitrogen as rapidly as it does the other gases it has taken up. The bubbles of nitrogen remaining in the blood cause the pain and fatality.

Variations in *temperature* are of importance in temperate and arctic zones.

Low temperature causes chilblains, frost bites, and freezing. In colder climates these injuries are of more serious concern. Two hundred and eighty-seven persons died of excessive cold in the area of registration[1] in 1932.

Cold may lower the temperature of the body and thus reduce its resistance to disease. Experienced observation has led the nose

[1] The "area of registration" in 1932 included 47 states, the District of Columbia, the territories of Hawaii, Puerto Rico, and the Virgin Islands. These figures, as well as most of the others in this chapter, are taken from *Mortality Statistics, 1932,* United States Bureau of the Census.

and throat specialists to the belief that the cooling effects of the swimming pool and of surf-bathing, of sleeping out of doors, and wearing scanty clothing increase the hazard of chronic infections of the sinuses. Damp, cool climates seem to have the same influence.

High temperature may cause: (1) Heat stroke—a result of hot, moist weather—maybe headache, rapid pulse, rapid respiration, loss of consciousness, death. In 1932, area of registration, there were 689 deaths from the effects of heat. (2) Burns; may vary in degree from simple redness to cremation. Death follows if half the body is burned enough to cause blisters. Death follows if from one-sixth to one-eighth of the skin surface is destroyed by burning. Burned areas are easily infected. The septic wounds that occur in such areas are often very serious. The scars that follow burns may cause incapacitating deformities. In the area of registration (1932) there were 5,358 persons accidentally burned to death; in addition, 1,555 lost their lives in conflagrations.

The importance of conflagrations in relation to poor health, disease, and death is by no means confined to losses of life by being burned to death. The economic losses from fire affect the nutrition of families and reduce their financial ability to purchase other health necessities. Property loss from fires, as estimated by the National Board of Fire Underwriters, totaled in 1934 about $263,000,000. This figure is somewhat lower than that of 1933 and only about half as great as several previous years, when the losses approached $550,000,000 annually.

Accidental loss of life due to burns in 1933 was exceeded only by accidents due to motor vehicles and falls.

Accident Facts reports that 7,341 persons died as a result of burns in 1933. This type of accident accounts for about one-fourth of all the accidental deaths of children under five years of age.

Light as a source of injury to health.—Insufficient sunlight is not a specific cause of disease, but it does contribute to produce, or help produce, poor health. We have noted on a preceding page that along with certain dietary deficiencies insufficient ultraviolet light has a causal relation to rickets. Insufficient illumination is a factor in causing eye strain.

Excess of light, particularly sunlight.—The red rays of the sun produce heat. They are factors in heat stroke referred to above. The violet rays and the ultraviolet rays of the sun are of

special importance. In excess, they may cause sunstroke when the rays of the sun fall directly on the head and neck. The symptoms of sunstroke are pains in the head and neck, nervous excitement, convulsions, and loss of consciousness. Death may come in an hour. In the summer of 1916, fifty-eight persons in New York City died of sunstroke. Milder cases recover, but they frequently develop a permanent nervous disorder of some sort. These rays (violet and ultraviolet) cause sunburn. Severe sunburn is very painful. The burned area may easily become infected.

The *X-ray* and *radium rays* are sometimes causes of disease among the specialists who work with them. Too frequent use of these rays may cause sterility in men and women. If applied too long, they cause "burns." Repeated excessive irritations from these rays develop cancerous growths.

Electricity as a physical cause of health injury.—Lightning may cause death or prolonged unconsciousness. Burns from lightning heal very slowly. Commercial electricity used for service and for industrial purposes is frequently the cause of injury. The seriousness of this injury depends on the amount of current that passes through the victim, the area of contact, and the region affected. Currents of low voltage and moderate frequency may be fatal if the heart is in the circuit. The electric current may cause nervous disturbances, burns, loss of vision, and death. Five hundred and eighty-nine deaths were reported from electricity (lightning excluded) in 1932 in the area of registration. It not infrequently happens that the heart continues to beat after breathing has been stopped by the electric current. In such cases the use of artificial respiration may save the victim from dying. (The best method of artificial respiration is the Schafer or the prone pressure method.) One should never handle loose electric wires and switches, unless he is certain of their safety and of his own protection. One should be most careful to avoid contact with electrical fixtures with wet hands. Bathroom fatalities from contacts with electrical fixtures are common because the wet skin offers little resistance to (i.e., is a good conductor of) electricity. Carelessness often leads to fatality.

CHAPTER XXVIII

CHEMICAL DISEASES DUE TO ACCIDENT, CRIMINAL INTENT, OR OCCUPATIONAL EXPOSURE[1] AND TO DRUG HABITS

I. Chemical Poisons through Accident, Criminal Intent, and Occupational Exposure

Evidence of chemical disease.—(*a*) Acute chemical disease. Following the rapid absorption of sufficient amounts of any one of the majority of chemical poisons, there will be immediate evidence of illness. This rapid development of an illness constitutes an acute disease. (*b*) Chronic chemical disease is caused by the slow absorption of relatively small amounts of the chemical at intervals during a period of weeks, months, or years. A chronic disease is a disease that develops slowly and continues for months or years unless successfully treated. (*c*) The symptoms of chemical disease are acute or chronic. Acute symptoms appear suddenly with little or no warning. They may consist of dizziness, headache, stomach-ache, nausea, vomiting, diarrhea, paralysis, convulsions, loss of consciousness, or sudden death. These symptoms may be caused by chemical poisons or bacterial poisons. It may be difficult to decide which. Only the expertly prepared, medically trained physician can discover the cause with certainty, and even he may not be able to make an accurate diagnosis without further careful examination. Symptoms of chronic chemical disease appear more gradually. They may not be noted or understood for weeks or months. When they do appear they may be as severe and explosive, and give evidence of injuries as great, as those that cause the symptoms of the acute disease. This is logical, because in either an acute or chronic disease due to the same chemical cause the injuries done the tissue cells and organs of the individual are identical. In the one event the damage is done rapidly. In the other, it is produced slowly. In contrast with the chemicals that cause illnesses with such symptoms as those described above, there are a few other chemical poisons that produce unconsciousness with little or no preliminary disturbance.

[1] The information in this chapter relative to occupational poisons is based largely on the facts presented by Alice Hamilton, M.D., *Industrial Poisons in the United States* (The Macmillan Company, 1925).

Identification of the cause of a chemical disease.—The diagnosis of a chemical disease due to accident, criminal intention, or occupational exposure may depend on a careful examination of the history of the individual and the symptoms of the attack, and on an analysis of the blood, urine, and feces. Obviously, a safe diagnosis ordinarily may be made only by a competent medical examiner.

We have known for a long time that certain chemical compounds injure the health of plants or animals or human beings and that they may be fatal. For instance, the physicians of Greece two thousand years ago and more had noted the poisonous effects of lead. History abounds in records of the uses made of various poisons for the removal of enemies. Today, compounds of known chemical substances are employed to destroy the bacteria that cause disease and to kill weeds, insects, vermin, and predatory animals. These chemicals are specific. Each acts in ways that enable the specially informed examiner to recognize it as the cause of the death under his observation whether it be animal or human.

Tragic accidents following the careless, inappropriate use of powerful drugs by some member of the home circle demonstrate somewhere in this country almost every day that such medicines unwisely used are specific causes of health injury and death. Accidents in the shop or factory bring disease or death because of the unvarying action of poisonous chemical compounds employed therein for purposes of manufacture or trade. The experiences of those industries concerned with the production or preparation of these chemicals or that employ processes in which such chemicals are used prove that the exposure of workers to them may result in acute poisoning, or in chronic disease. This fact is so important that it has forced the attention of employers, labor unions, and governments to the problems of prevention, care, and cure.

These and other experiences teach that there are many chemical compounds that destroy health and life. We noted above that sometimes this action is rapid and may be described as acute poisoning, but that more often the poison is received in small amounts over a long period of time, so that the poisonous action develops slowly and causes a chronic poisoning. We have thus in the one case an acute disease and in the other a chronic disease—or in either case, death—caused by a specific chemical agent.

In addition, there is convincing evidence that workers exposed

to lead poisoning may not only suffer health injury themselves, but may also communicate such injury to their children. Thus a chemical cause of disease may injure the health of an unborn child, destroying its life before or soon after birth, or it may cause an injury to a child that survives, incapacitating it more or less completely for life. It is possible that lead poisoning may damage the germ-cell, injuring the heredity it carries and causing thereby a heritage of disease. There is record of "leaded" fathers and healthy mothers whose children are born with evidence of the effects of the father's disease.

The chemicals involved.—The chemicals that cause disease most frequently through accident, criminal intent, or occupational exposure are compounds of lead, arsenic, phosphorus, mercury, petroleum distillates (e.g., naphtha, benzin, and petroleum ether), coal-tar distillates (e.g., benzol or benzene, anilin, and nitro-benzene), carbon disulphide, wood alcohol, carbon monoxide, and hydrogen sulphide. There are other chemicals in the classification we use here, which are less commonly causes of disease.

Places of exposure to the chemical causes of disease.—The hazard of exposure to chemical causes of disease is present wherever such chemicals are mined, manufactured, handled, or used. Among such places are certain mines, industries, trades, and professions. They are found also in the home as drugs, alcohol, insect and vermin poisons, cleaning fluids, gas for illumination or heat or the exhaust of gas engines (automobile), in paints, varnishes, shellacs, and certain cosmetics.

Form in which injurious chemical agents reach the body.—The more dangerous forms are the poisonous chemical dusts, powders, gases, sprays, and fumes. Of lesser importance are the fluid, semi-fluid, and solid forms.

The most important poisonous chemical dusts are those that are produced in the various industrial processes in which lead compounds are used. The most important lead dust is probably that which is formed by the painter when he smooths one coat of lead paint, usually by sandpapering, before he applies the next coat. The lead paint dust that he produces by smoothing successive coats of paint fills the air he breathes and this reaches the surface of the lining of his nose and other air passages. Other important poisonous chemical dusts are formed from various compounds of arsenic, mercury, manganese, and zinc.

Among the gases, the most important chemical cause of disease is carbon monoxide present in the exhaust of the automobile and in illuminating gas (coal gas and water gas, but nevertheless very poisonous). Among the lesser important gases are the arsenical gases, chiefly arsine, the fumes or vapors of mercury, white phosphorus, hydrogen sulphide, and carbon disulphide.

The vapors of petroleum distillates—gasoline, benzin, naphtha, petroleum ether—are poisonous. The fumes of wood alcohol (methyl alcohol) are very poisonous, also the fumes of the chlorin derivatives, carbon tetrachlorid, and tetrachlorethane. Benzene (or benzol) is a coal-tar distillate. It is a very volatile fluid, the fumes of which are poisonous.

Avenues through which the chemical causes of disease enter the body.—Gases, fumes, vapors, sprays, and dust may be inhaled and thus come in contact with the mucous membrane lining of the nose. Fluids, semi-solids, dusts, and powders may be swallowed with food or drink or carried to the mouth on the fingers or pipe and thus come in contact with the walls of the mouth and the digestive tract. Fluids, pastes, smears, powders, and dusts may take effect directly through the skin.

In order that a chemical poison may enter the body it must be carried by the blood. The chemical dusts must be dissolved on the surfaces of the air passages or of the digestive tract before they can be absorbed. The vapors, fumes, and gases are ready for absorption.

Conditions of the individual that favor chemical injury.—*Age:* The younger the individual, the more susceptible he is to chemical influences. This is true of drugs administered for desirable medical purposes. Medication of the expectant mother, if it enters her blood circulation, will affect her unborn child. Such a mother suffering from a chemical poison will distribute the poison to her child if the poison is carried in her blood stream.

Sex: Women and girls are more easily injured by the chemical causes of disease than men and boys.

Menstruation and pregnancy: These periods in the lives of girls and women are periods of greater susceptibility to certain chemical poisons, notably benzene.

Individual differences in susceptibility to chemical causes of disease.—Differences in reaction to chemicals used for medicinal purposes are expected by the experienced physician. The

same differences exist in the vulnerability of individuals to bacterial poisons and to the chemical poisons. Some individuals are excessively sensitive. Others are less sensitive. Some are almost immune to certain chemical poisons even as some are to certain bacterial poisons.

Effect of degree of exposure.—Acute poisoning with characteristic evidence of poisoning occurs when the amount of the dose is large. But with smaller amounts the poisoning may be slow and escape notice until the disease becomes chronic. A long-used headache powder, a slow gas leak, long hours of exposure to an industrial poison diluted in the air, food, or water, may eventuate in health injury, unsuspected until well established.

Defenses against the chemical causes of disease.—These hazards may be controlled by safeguards that make it impossible for individuals to be exposed to the chemical causes of disease. Such control involves, first, "isolating" the chemical cause to the extent that it is not exposed to the individual; second, "isolating" the individual so that he does not expose himself to the chemical cause. The cause may be isolated by keeping it away from the individual, out of his reach, out of the air he breathes, the water he drinks, or the food he swallows. The individual isolates himself by his habits of cleanliness, by his habits of safety, and by his observance of safety regulations.

The prevention of accidental poisoning in the home deserves forehanded care. Drugs and other dangerous chemicals (insect powders and rat poison, for instance) are less hazardous when they are stored under lock out of the reach of young children. Drugs should never be taken without first a verifying examination of the label. Many acute poisonings, some of them fatal, would be avoided if more people had the habit of reading their drug labels carefully and under good illumination before taking their medicines. Drugs should not be taken without the advice of the trusted physician. Their use should not be long continued without such advice.

The prevention of injury from the chemical causes of disease in the industries is obviously a problem of the employer on the one hand and the employees on the other. The employer's responsibility is to supply his employees with (1) air that contains no poisonous dust, spray, fumes, vapors, or gases; (2) facilities and opportunities that will enable his employees to clean themselves

and their clothing adequately before eating and before leaving their place of employment; (3) devices for emergency service, such as gas masks. It is his obligation to make poisoning among his employees as nearly impossible as can be by way of air, lunch, drinking or wash water, and other contacts. This obligation in the industries cannot be satisfied without the aid of specially qualified engineers and technicians. It cannot be satisfied without the aid of expert, specially qualified medical service and a competent program of pre-employment health examinations, periodic examinations, and constant health observation, with early availability for consultation open to all employees who wish for health advice.

The responsibility of the employee is to inform himself concerning the health risks of his job; to understand and observe all safety regulations; to keep himself clean; and to co-operate in safeguarding his fellow-workers.

Experience establishes the fact that not all employers meet their ethical responsibilities to defend their employees against hazardous occupational exposure. Not all employers have awakened to the business fact that the eradication and control of these hazards in the long run produce greater profits. And experience teaches also that employers are often uninformed, misinformed, or careless in relation to the health hazards of their work. Obviously then, a successful defense against the chemical causes of occupational diseases depends on (1) defensive societal hygiene furnished by public education, public information, community standards, scientific legislation, supporting customs, and favorable mores and folkways; (2) defensive group hygiene furnished by the single industrial group whether it be a mine, smelter, paint shop, rubber factory, or other plant that provides (*a*) the appropriate structure and adequate safety, sanitary, and emergency equipment, (*b*) pertinent informational publicity among group members, (*c*) practical regulations for prevention and defense, (*d*) competent staff and program for the health examinations, advice, and treatment of employees; (3) defensive individual hygiene furnished by employees who are correctly informed concerning the health hazards of their occupation and whose health habits not only safeguard themselves but also safeguard their fellow-workmen.

Examples of the more important chemical diseases due to accident, criminal intent, or occupational exposure follow. A knowl-

edge of the symptoms, diagnosis, prevention, and treatment of these diseases is not a knowledge that should be expected of the lay citizen. The chemical diseases belong to the field of the medical specialist, even as the microbe diseases or the nutritional disorders do. The following details are presented for the emphasis they give to the importance of the chemical diseases and not with the expectation that the lay student will attempt to retain them in his memory.

Lead poisoning (plumbism).—Acute lead poisoning in fatal cases produces a violent colic with intense pain. In the great majority of cases the poisoning is of slow development and the disease then becomes chronic. It is characterized by (1) attacks of agonizing abdominal pain (lead colic); (2) severe pain in the larger joints (lead arthralgia); (3) muscular paralysis (lead palsy) with progressive muscular weakening and atrophy; (4) mental disturbances (lead encephalopathy) and nervous involvements, the combination including such manifestations as delusions, maniacal excitement, delirium, unconsciousness, optic neuritis, hysterical reactions and convulsions; and (5) hardening of the arteries (arteriosclerosis) with contracted kidneys and enlarged heart.

The lead attacks the muscles in the walls of the smaller arteries, causing them to thicken and harden, thus diminishing the amount of blood they can carry and reducing the nutrition of the cells of the organs depending on them for their supply of food.

We noted above that there is some evidence that lead does damage to germ-cells, injuring at least temporarily the heredity they carry and producing, thereby, nervous disorders, epilepsy, imbecility, and idiocy in offspring. There is more convincing evidence that the circulation of lead poison is a cause of serious injury to the fertilized ovum or embryo or foetus, destroying life before birth or soon after, or causing mental, nervous, and physical incapacities that are handicaps through life.

Where lead poisoning takes place.—Victims of lead poisoning are found among lead miners, men who work in lead smelters and refineries, and in zinc smelting. Cases of poisoning are common among workmen who are engaged in casting or molding metallic lead under conditions that expose them to fumes from the lead pots and to lead dust. Men in the printing trades are exposed to poisoning from lead dust and possibly lead fumes produced in

various details of such work. Lead poisoning occurs among laborers in the white- and red-lead industries in which the processes of manufacture are accompanied by uncontrolled production of lead dust. The use of white and red lead for the manufacture of storage batteries is a prominent factor in several large and many small factories in the United States. The details of the several stages of the process of making storage batteries make the trade dangerous as a source of lead poisoning mainly because of the fumes from melted lead and because of the dust from the lead used in pasting plates and in assembling and soldering the formed plates.

The menace of dust and sprays containing lead is great in plants engaged in glazing, enameling, and pottery making.

Lead poisoning is especially important among painters who use lead paint because the painter's trade is represented in every community. The danger comes mainly with sandpapering or otherwise smoothing the surface of one coat of paint before applying the next coat. This smoothing produces lead dust, which the painter can hardly avoid inhaling. It is probable that the paint smeared on the hands finds its way to the mouth either at meal time or by handling a pipe. The use of quick-drying paints and the spray gun for painting is inevitably accompanied by loading the air with the spray and with gases given off in the process of rapid drying. If lead paint is used, the danger of lead poisoning is obvious.

In addition to the occupations that have been mentioned, Doctor Hamilton describes a number of miscellaneous lead trades in which lead poisoning occurs. They are grinding paint, making litho-transfer papers for decorating pottery, the painting of mechanical or commercial artists, polishing cut glass with putty powder made of oxids of tin and lead, polishing brass, lead tempering of machine parts, compounding rubber with lead in one form or another as an ingredient, vulcanizing by heat with the aid of lead, the reclamation of rubber from the grinding of old rubber, making lead wool or lead rope, and the use of putty containing lead in glazing.

Among the other numerous occupations not already mentioned in which poisoning from lead has been recorded in the United States, the following suggest the ease with which one may be unknowingly exposed to this hazard: cleaning white shoes with a combination of talcum, lead white, and benzene; using lead colors

to paint labels on bottles; making artificial flowers; repairing wooden storage-battery boxes; using the mouth to hold nails covered with lead while shingling a roof or cobbling shoes; and using cosmetics containing lead.

Forms in which lead comes into contact with the body, and avenues of entry.—Industrial dust is the most common carrier of lead. Air laden with lead dust or containing lead fumes brings the lead in contact with the lining of the nose and other air passages. The absorption of lead from the respiratory tract is the most common avenue of lead poisoning.

Of lesser frequency is contact with lead swallowed in drinking water or with food. Not so common is the absorption of lead through the skin from smears of lead mixed with oil in paint, lead in cosmetics, and in hair dyes.

Defense against lead poisoning.—The prevention of lead poisoning is of very great importance in a great many industries and trades. Its achievement depends mainly on a reduction in the production of lead dust and fumes and on the control of the dust and fumes that are produced so that they will not come into contact with the skin or mucous membranes of exposed persons. This control in any given plant is likely to present local, difficult, and unique problems of ventilation that tax the ingenuity and resources of the management. Such details are beyond the scope of this text.

Arsenic poisoning.—Arsenic has been known and used as a poison for a long time. Its value as a medicine for the curative treatment of certain diseases, notably syphilis and yaws, is established. Its relation to accidental poisoning, to suicide, and to homicide is well known. It is responsible also for certain occupational diseases.

Arsenical poisoning may be acute or it may be chronic. When arsenic is swallowed it causes disturbances of the digestive tract, and vomiting occurs. There are muscle cramps and paralysis. Death may be the end. Arsenic dust causes skin sores that may ulcerate. These injuries are particularly evident in occupations in which this dust is formed, as in packing Paris green or the arsenate lead. If the dust is inhaled it irritates the lining of the nose, causing ulceration, a not uncommon experience of men working in copper smelters in which dust containing arsenic trioxide is present. Laryngitis and bronchitis are caused by arsenical dust.

Inhalations of arsenical gas or fumes are especially damaging to the red blood cells. Extreme anemia may follow.

The more important exposures to arsenical poisoning are the family medicine chest or the domestic storeroom, where it may be mistaken for something else, found by unsuspecting children, or used by suicidal or criminally minded adults; mining and smelting metal ores, especially lead smelters and copper smelters, the unguarded fumes of which may spread arsenical dust over the surrounding territory; the manufacture and use of Paris green (aceto-arsenite of copper); the manufacture and use of lead arsenate; the manufacture of arsenical colors; the use of arsenical colors for dyeing fabrics, as in certain wall papers from which the arsenic may be released as a very poisonous gas through the action of a mold (*Penicillium brevicaule*) which in the presence of moisture grows in the paste that fixes the paper to the wall; all the industrial processes in which the formation of arsenical dust or arsenical gas (hydrogen arsenid or arsin, AsH_3) is not controlled with complete safety to employees or the general public.

Carbon monoxide.—Poisoning from this gas is the most important of all gas poisonings. More lives are lost from it than from all other gases combined. It is prominent as an industrial hazard and as a result of accidental exposure to escaping illuminating gas and the exhaust gas of automobiles. Suicide with illuminating gas is common. Carbon monoxide is colorless, practically odorless, and tasteless. It has no irritating effect on the lungs. Its presence in the air is not easy to detect, especially when it is slowly added as in the case of the common leaky gas pipe.

Sources.—The common sources of carbon monoxide are (1) illuminating gas (both coal and water gas); (2) the exhaust gas of gasoline engines, especially the automobile; (3) blast furnace gas; (4) mine gas, including the gases from explosives, fires in the mines, explosions of coal dust, and gases given off by shale. Under ordinary circumstances the hazards of carbon monoxide poisoning are found in leaking gas fixtures, coal fire-places with poor drafts, coal furnaces and stoves that are dampered too soon, defective flues, certain gas heaters, and in carelessly running the motor in a closed garage.[1]

[1] Milton J. Rosenau, *Preventive Medicine and Hygiene* (D. Appleton & Company, 1927), p. 856.

Mode of entrance.—Poisoning by carbon monoxide occurs as a result of breathing air that contains it. This gas is not a true poison. It causes injury because its power of combining with the hemoglobin of the red blood cells is between two hundred and three hundred times that of oxygen. If one continues breathing a mixture of two parts of CO (carbon monoxide) to one thousand parts of air his red blood cells slowly become saturated with CO to the exclusion of oxygen. Such a mixture breathed for four or five hours results in death. In this connection it is important to note that injury from CO arrives more rapidly if the individual is working muscularly while he is breathing an atmosphere containing carbon monoxide. Hamilton[1] reports Haldane as stating that a normal man at rest satisfies his muscular and other tissue cells with a little more than one-third of the oxygen brought them by his blood. But when he becomes muscularly active, about two-thirds of the oxygen carried by the blood is used. This increase in the oxygen requirement explains the fact that one may be at rest with his red blood cells nearly one-third saturated with carbon monoxide and not realize his peril, and then collapse in his effort to escape. These facts explain the reason why rescue parties sometimes suffer more severely than the victims they rescue.

Symptoms.—With acute carbon monoxide poisoning the onset "may be as sudden as a stroke of lightning" (Hamilton). There may be a warning in the form of a dizziness, blurring of the vision, weakness of the knees, dry mouth, nausea; there may be stupor and mental confusion. Loss of consciousness is common.

Recovery is rapid if the individual is restored to an atmosphere of fresh air before he has been too long subject to oxygen deprivation. With more severe poisonings there may be a later pneumonia, heart injury, paralysis, and transient or permanent mental disease.

Prevention.—The prevention of CO poisoning is accomplished by (*a*) safe gas fixtures. "It is a hygienic paradox in the United States that we have strict laws concerning plumbing, but any old gas fixture will do" (Rosenau); (*b*) adequate ventilation; (*c*) pertinent public information; and (*d*) the elimination of carelessness.

[1] Alice Hamilton, *Industrial Poisons in the United States* (The Macmillan Company, 1925), p. 371.

II. Chemical Poisons Due to Drug Habits

In the group of chemical diseases due to drug habits the most important chemical poisons are the organic chemicals alcohol, opium, morphine, and cocaine.

Alcohol.—Varieties of alcohol. Methyl alcohol, a very dangerous poison, is known as wood alcohol. It is used to adulterate cheap whiskies and for numerous commercial purposes. Ethyl alcohol is the main factor in alcoholic drinks. The higher alcohols (fusel oil) are relatively unimportant poisons.

Ethyl alcohol.—In 1932 the death-rate due to acute alcoholism was 2.5 per 100,000 population in the area of registration.

There is no difference of opinion concerning the injuries to health and life that follow alcoholic excesses. The alcoholic is of weak will and blunted moral sense. He loses his feeling of domestic and community obligation. The drunken father and the drunken mother destroy themselves physically, mentally, and morally, and their children suffer because of their tragic injuries of character and personality and of social opportunity that make it extremely difficult for them to escape poverty, ignorance, delinquency, crime, and disease.

There is, however, authoritative difference of opinion as to the effects of moderate drinking and temperance on health and longevity. The facts supporting one point of view are presented by the Life Extension Institute, as follows:

The mortality bill against alcohol.[1]—In a number of life insurance companies, chiefly in Great Britain, the abstainers were separated from the rest of the policyholders (all accepted as temperate and healthy risks), and the difference in the death-rate determined. In the United Kingdom Temperance and General Provident Institution of London over a period of forty-five years the mortality of the non-abstainers, or so-called moderate drinkers, accepted as temperate and healthy risks was 37 per cent higher than that among the total abstainers. In the Sceptre Life Association of London over a period of twenty-seven years the mortality of the non-abstainers was 54 per cent higher than among the total abstainers. In the Scottish Temperance Life Assurance Company of Glasgow over a period of twenty-nine years the mortality of the non-abstainers was 55 per cent higher than among abstainers. In the Manufacturers' Life Insurance Company of Canada over a period of eight years the mortality of the non-abstainers accepted as temperate and healthy risks was 78 per cent higher than among the abstainers. There has recently been compiled the experi-

[1] Life Extension Institute's *Monthly Letter, No. 12.*

ence of forty-three American life insurance companies extending over a period of twenty-five years. The death-rate among certain types of drinkers was compared with that among insurance risks generally. The results follow, supporting the evidence derived from British companies: First, those who were accepted as standard risks but who gave a history of occasional alcoholic excess in the past. The mortality in this group was 50 per cent in excess of the standard mortality, equivalent to a reduction of over four years in the average lifetime of the group. Second, individuals who took two glasses of beer, or a glass of whiskey, or their equivalent, each day. In this group the mortality was 18 per cent in excess of the standard. Third, men who indulge more freely than the preceding group, but who were considered temperate and acceptable as standard insurance risks. In this group, the mortality was 86 per cent in excess of the standard. In short, we find among alcohol users the following increases of mortality over the standard or average death-rate among insured risks generally:

Death-Rate in Excess of Standard

Steady moderate drinkers, but accepted as standard risks	86 per cent
Having past excesses	50 per cent
Very moderate drinkers	18 per cent

This means that steady drinkers who exceed two glasses of beer or one glass of whiskey daily should be charged a heavy extra premium, and that there is a distinct extra hazard even on those who drink to a lesser degree. In these groups the death-rates from Bright's disease, pneumonia, and suicide were higher than the normal. Unfortunately, in the investigation of American companies, no comparison was made with total abstainers. It is evident, however, from the trend of the figures and the results shown by British companies that such comparisons would show the abstainers to have a long lead in vitality over the very moderate drinkers.

The facts in support of the contention that moderate drinking and temperance are not causes of health injury are summarized by Raymond Pearl[1] after a 225-page analysis, as follows:

The results of the investigation which this book reports can be stated in much less time and space than the work itself required. They are:

1. In a fairly large and homogeneous sample of the working-class population of Baltimore the moderate drinking of alcoholic beverages did not shorten life. On the contrary, moderate, steady drinkers exhibited somewhat lower rates of mortality, and greater expectation of life than did abstainers. This superiority is not great in the male moderate drinkers, and may not be significant statistically. But it certainly gives no support to the almost universal belief that alcohol always shortens life, even in moderate quantities.

[1] Raymond Pearl, *Alcohol and Longevity* (Alfred A. Knopf, 1926), p. 226.

2. Those persons in this experience who were heavy drinkers of alcoholic beverages exhibited considerably increased rates of mortality and diminished longevity, as compared with abstainers or moderate drinkers.

3. If both moderate drinkers and heavy drinkers in this sample of the population are pooled together, and the resulting heterogeneous group is compared with abstainers, the drinkers, as a class, have higher rates of mortality and lower expectation of life than the abstainers as a class. This result is in agreement with the experience of life insurance companies. But it is fully demonstrated in this book that this result appears only because the impaired heavy-drinker risks are pooled with the actually superior moderate drinkers, and bring down the resulting pooled average.

4. Experiments by various workers, on such different forms of life as guinea pigs, fowls, rats, mice, rabbits, frogs, and insects, agree in showing a beneficial effect of alcohol upon the race. This beneficial effect appears to be produced chiefly as a result of the remarkably sharp and precise selective action of this agent upon germ-cells and developing embryos, killing off the weak and defective and leaving the strong and sound to survive and perpetuate the race. The prevalent notion that parental alcoholism tends to cause the production of weak, defective, or monstrous progeny is not supported by the extensive body of experimental work which has been done on the problem. Only one recent, critical experimenter has ever reported the production of defective offspring following parental alcoholism, and his results respecting this point are definitely not confirmed by another competent worker with the same animal, the guinea pig.

It seems clear, and entirely just, that anyone disagreeing with the conclusion reached in this study that there is no impairment of the life duration of moderate drinkers as compared with abstainers must assume the burden of proof as to why the present considerable mass of objective data do not show a result opposite in sense to that which they do in fact show regarding this point. I am in no way constrained to explain why moderate drinkers and abstainers show similar life expectancies at all ages. I am content to rest upon the fact that it is so in the present statistics. On the principle of Occam's razor (*Entia non sunt multiplicanda praete necessitatem*) the most probable explanation seems to me to be the simple one that the moderate consumption of alcoholic beverages has no deleterious biological effects. But since I have carefully refrained throughout the book from stating this as a general conclusion, I am in no wise obligated to prove it as such. Instead, it is sufficient for the present merely to draw the specific conclusion that in the considerable sample of the working-class population of Baltimore here studied, moderate drinkers did live, on the average, just as long as total abstainers, and in truth a little longer.

These, then, are the results of this investigation. They seem to indicate, with great clearness, that any biological harmfulness chargeable against alcohol, in this group of over 5,000 people, resulted solely from its abuse, and not from its reasonable and proper use. I said at the beginning of this book that the sole object of the study was to learn something about

the real or supposed social effects. Now that the work is finished I see no reason to change from this position. The social problem presented by alcohol seems to me to resolve itself finally into a matter of taste. The essential elements in the situation are these: (*a*) Alcohol when abused leads directly to more or less disastrous consequences; (*b*) some human beings are so constituted that they will abuse it, with greater or less frequency and regularity. Given this situation mankind divides itself promptly into two moieties, on the basis really of taste. Those in the one group feel it their most sacred duty to prevent the weak brother from getting the chance to liquidate his weakness in terms of this particular deleterious agent, at least. The other group feels that it is neither right nor decent to deprive the great bulk of normal humanity of a harmless source of pleasure in order that a small group of persons deficient in self-control may theoretically be kept out of temptation.

The difference between these two groups of honest and sincere human beings is, I repeat, at bottom a matter of taste, of general outlook on life. There is no more hope of reconciling such a difference than there is of getting all men to agree that Beethoven's music is preferable to Irving Berlin's, or that Mohammedan dogma is more satisfying than Christian, or that corned beef and cabbage is a more delectable dish than *confit d'oie*. To the resolution of such problems science can really contribute nothing effective. That elyng creature man is not a wholly rational animal in respect of his behavior. In fact, he only acts rationally, if by natural endowment capable of doing so, when the consequences of failing so to act are immediately and sufficiently painful. Otherwise his emotions and tastes get full play. Up to the present time the consequences of minding other people's business relative to this volatile compound, on the other hand, have in neither case been sufficiently painful to bring about anything approaching universally rational control of behavior in the premises.

Finally, I must expressly disclaim any responsibility for the application of the results of this investigation to the business of individual human living. Whether any particular person chooses to be a teetotaler, a moderate drinker, or a sot is a matter to be decided between himself, his inherited constitution, and "whatever gods may be." The only pertinent advice I can give him is that he learn, by precise experimentation, what constitutes moderate drinking *for him*. Nothing emerges more plainly from all the scientific work that has been done on alcohol than that individual tolerance to alcohol is a highly variable phenomenon. Also it will be the part of wisdom to remember that a conclusion which is on the average true for a large statistical aggregate may not be so for a particular individual in that aggregate.

Prevention.—Many books are written on alcoholism and its prevention, and we have had a constitutional amendment designed to stop it. It is a matter of personal and community concern. Alcoholism can be controlled only by the habits and attitudes of in-

dividuals. If a sufficient number of men and women control themselves and insist on the protecting of their lives and health, and their homes and communities, the menace of alcohol would cease to be important.

Opium and its derivatives.—In this group are opium, morphine, codein, heroin, and other lesser important drugs.

These organic chemicals, called alkaloids, are secured through direct purchase, physicians' prescriptions, or in patent medicine. Opium may be smoked. It and the other derived drugs are more commonly taken by mouth or hypodermically. Laws are formulated in many states to restrict the sale of such drugs. We have also a federal law to this same effect. Medical teaching nowadays is directed against such use of these drugs as may lead to habit formation. These drugs cause acute poisoning if taken in any but small doses. Death may and does easily follow. These drugs are taken by unfortunate human beings who have formed a habit of using them. At first, small doses produce cessation of pain, and sleep. The habit is easily formed. After a while it takes more and more of the drug to satisfy the victim. Very undesirable effects soon appear. With the smoker of opium the will is weakened. There are loss of memory, despondency, suicidal tendency, general tremor, a deathly pallor, failing eyesight, rapid pulse, chronic bronchitis, indigestion, constipation, itching skin, and often vomiting. With those who take opium by mouth there is finally a degeneration of mind, morals, and physique. There is a loss of self-respect, with insomnia, emaciation, and a tendency to melancholia, dementia, and often sudden death. With those who take morphine by mouth or the hypodermic there are three stages of the disease: exaltation, intoxication, and emaciation. The habitué ends by loss of character, will, and morals. He is beset with nightmares. His hair falls out; his teeth decay; his face is drawn and aged. Emaciation becomes extreme. A continual delirium may ensue and death ends the habit. The habitual use of morphine and its derivatives is very difficult to break. It is better never to know what drugs one takes. Leave that knowledge with the doctor. One should choose his physician with the greatest of care and then trust him.

Cocaine.—This drug is present in certain prescriptions and patent medicines. It is used habitually by the same type of persons that use opium and morphine. It is taken hypodermically,

or snuffed, or taken by the mouth. Very small doses sometimes cause death; the sense of sight, hearing, and smell become seriously impaired. The patient hears persecuting voices, and sees strange threatening objects. A delusional insanity develops. Suicidal or homicidal impulses may appear. This drug is more quickly and intensely destructive than alcohol or opium (Lambert).

Remember: Alcohol, opium, morphine, and cocaine are common habit-forming drugs. You should take no chance leading to the formation of such habits. Avoid drinks and patent medicines containing these poisons.

Tobacco.—The injuries that may result from the use of tobacco are probably of chemical origin. We possess no accurate information as to the exact nature of the chemical actions involved. The use of tobacco is often attended with such phenomena as nausea (ordinarily only in beginners); "sour stomach," indigestion; ulcer of the stomach; slightly increased heart rate; moderately increased blood pressure; wakefulness; nervous irritability; lessened accuracy of muscular co-ordinations; increased susceptibility to fatigue; and dry and irritable lining (mucous membrane) of the nose, throat, tongue, and mouth.

Evidence has been produced which would seem to show that only half as many smokers as non-smokers are successful in the "tryouts" for football squads; in the case of able-bodied men, smoking is accompanied by a loss in lung capacity amounting practically to ten per cent. Track coaches and the coaches and trainers of athletes in other forms of competition invariably advise against the use of tobacco.

The tobacco habit is not a clean habit. It is frequently offensive to non-users and is the basis for much bitterness on the part of such non-users, because of the lack of consideration shown them by smokers. It is evidently unwise for children, young adults, and delicate, sickly, nervous, or irritable persons to use tobacco. The habitual smoker should seek regular, careful medical examination for the early detection of such injuries as have been noted above.

CHAPTER XXIX

PATHOGENIC MICRO-ORGANISMS THAT INJURE HEALTH

The discovery of pathogenic micro-organisms.—So far as we know the world of microscopic organisms was unseen before the monk, Athanasius Kircher, with his crude microscope observed what he called "living worms" in 1659. The "father of microscopy," Anton van Leeuwenhoek, made a much better microscope and saw much more of the world of minute organisms that had been so long invisible. He saw and described in 1675 and thereabouts living spermatozoa, and active micro-organisms in the saliva and in stagnant water, diarrheal discharges, and in fermenting and decomposing fluids. This was a discovery of a new world that led, two centuries later, to the discovery of some of the most ancient and ruthless and powerful enemies of mankind, plant kind, and animal kind—the pathogenic bacteria and the pathogenic protozoa.

But it was more than two hundred years after van Leeuwenhoek before scientifically minded men had perfected the microscope and devised methods and techniques of research that enabled them to investigate the world of animalcule revealed by Kircher and van Leeuwenhoek and discover the germ causes of disease, prove their relations to disease, and establish methods of scientific prevention and treatment.

The greatest name in the list of those whose researches have given us this knowledge is that of Louis Pasteur (1822 to 1895). The life of this benefactor of the health of all living things—men, animals, and plants—makes thrilling reading.[1] It is a record of a chemist who became the founder of the sciences of biology, bacteriology, and immunology. Among Pasteur's outstanding achievements are his proof (1) that each fermentation is produced by the development of a special living microbe; (2) that each infectious disease is produced by the development within the individual of a special living microbe; (3) that the virus of an infectious disease if cultured under detrimental conditions is attenuated in its virulence. From a virus it becomes a vaccine. Pasteur's discovery of the use of attenuated viruses for purposes

[1] René Vallery-Radot, *The Life of Pasteur* (Doubleday, Page & Company, 1923).

of immunity (vaccination, etc.) has saved millions of animals and millions of men, women, and children. (The significance of these statements will be more clear to the reader after their consideration in the text below.)

For hardly fifty years we have been learning how to study these organisms. Great names of such men as Pasteur, Koch, Weigert, and Ehrlich are on the list of those who have solved the mystery of the microscopic pathogens and their tragic invisibility throughout the preceding ages of ignorance and fear. Because of the scientific vision and because of the painstaking scientific methods of these and hundreds of others we are able to describe the pathogenic bacteria and the pathogenic protozoa and indicate with certainty some of their modes of action and some of our opportunities for successful defense and effective prevention.

The bacteria.—Bacteria are very small. They are generally regarded as plants. They are invisible to the naked eye. Some are so small as to be invisible to any but the most powerful microscopes. We have reason to believe that there may be some bacteria too small to be seen with any means now known to science.

There are two broad classes of bacteria, e.g., those that cause disease—the pathogenic bacteria—and those that do not cause disease—the non-pathogenic bacteria. Unfortunately, it seems to be true that under certain conditions non-pathogenic bacteria may become virulent, and therefore pathogenic. It is equally true, fortunately, that pathogenic bacteria sometimes lose their virulence, and thus become, temporarily at least, non-pathogenic.

The non-pathogenic bacteria.—The non-pathogenic bacteria exist in enormous numbers everywhere. They are far more numerous than the pathogenic bacteria. The cleanest milk you drink contains thousands and perhaps millions of them, in every swallow. Every cubic millimeter of the best city water contains them. Our surroundings, food, air, and water are infected by them. But these organisms are ordinarily harmless. Many of the non-pathogenic bacteria are not only harmless in their relation to disease, but are important in their beneficial relation to health and life. In fact, all human, animal, and plant life would disappear in the course of time if the valuable services of some of these bacteria should be lost.

The "carbon cycle."—Carbon is essential to the life of all plants. No plant can live without it. Commonly plants secure their

carbon from the carbon dioxide in the air. They "breathe" through their green leaves much as we breathe through the wall of our lungs. The plant retains the carbon and returns the oxygen to the air. The carbon is then used by the plant in building its structure. It is the chief chemical in wood. It is present in all fruits, vegetables, cereals, and other vegetable foods. Animals eat the plants and thus secure the carbon which the plants have used in producing their fruits, seeds, leaves, and stalks. Animals use this carbon in building their tissues, or in producing their secretions. Every tissue cell in the animal body contains carbon. Human beings eat plants, plant foods, and animals. Thus the human animal secures the carbon it needs for its cells from plant life. Every cell in every tissue and every organ of your body and mine contains carbon. Carbon is absolutely essential to all life, animal or vegetable.

Whenever a plant, or an animal, or a human being discharges excretions from any of its organs, those excretions contain carbon. Some of the non-pathogenic bacteria "feed upon" those excretions and break them up into simple chemical compounds. Carbon dioxide is one of the important products of the action of bacteria upon organic excretions. Whenever a plant, or an animal, or a human dies, the non-pathogenic bacteria "feed" upon the dead body and decompose it. They thus break up the complex chemical compounds into simple chemical compounds. Carbon dioxide is always produced in such bacterial action.

The carbon dioxide released by bacteria in their decomposing influence on the dead bodies of the plants, animals, and humans, and on the organic excretions, secretions, and discharges from those same sources, passes into the air, and is again available as plant food. It may be again breathed through the green leaves of living plants and thus continue the "carbon cycle."

It is obvious that this subtraction of carbon from the air and this addition of carbon to the air must balance. If, through the course of centuries, less carbon were returned than taken out, the air would finally have too little carbon to meet the needs of plant life, and plants and animals and humans could live no longer.

The "nitrogen cycle."—The nitrogen cycle is very like the carbon cycle except that nearly all plants secure their nitrogen compounds from the soil through their roots. When the non-pathogenic bacteria decompose dead human, animal, and plant bodies into simpler chemical compounds, they return nitrogen to the soil

in simpler forms that are again available for plant life. Some bacteria take nitrogen from the air and store it in the structure of the plant in forms available for animal food.

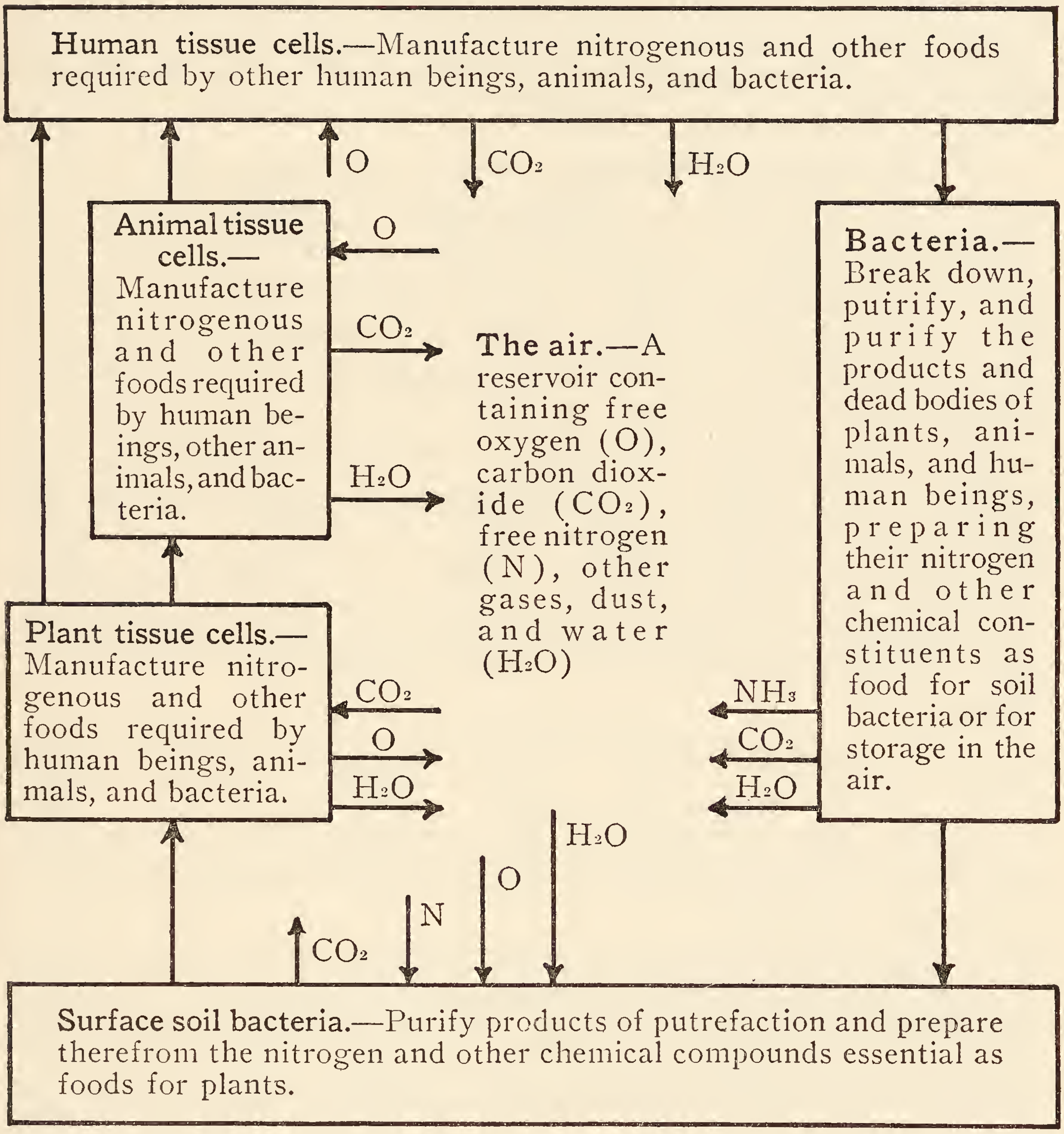


FIG. 55.—The Nitrogen Cycle. This illustrates also all other chemical cycles essential to life.

We have noted elsewhere that nitrogen is requisite for all human and animal life. Every tissue cell in our bodies must have nitrogen. If the non-pathogenic bacteria should "go out of business" there would be this second reason why all human and all animal life would disappear.

There are other chemical "cycles" of lesser importance, such as the "phosphorus cycle" and the "sulphur cycle." These cycles all demonstrate the fact that human life as we now know it would be impossible without the service of the non-pathogenic bacteria.

Commercial values of the non-pathogenic bacteria.—Some of these bacteria give flavor to butter. Others ripen cheese. Some are important in the manufacture of vinegar, acetic acid, the tanning of hides, and the curing of tobacco.

The pathogenic bacteria.—*Proof of pathogenicity.*—It is a serious matter to place the responsibility for causing a disease. It is important to make no mistakes. If we try to defend health and life from the wrong pathogen, the consequent loss of time, energy, money, health, and life may be tragic. Pasteur's research procedures give evidence of an alert appreciation of the importance of absolute proof. One reason for his success was his insistence on testing every possible probability of error in his experimental procedures. On the basis of Pasteur's methods and experiences and on the basis of his own, Robert Koch formulated a set of conditions that bacteriologists believe must be met in general before a bacterium may be accused of being the cause of a specific disease. These conditions are known as "Koch's Postulates." They are as follows:

1. The same bacterium must always be found with the same disease.
2. The same bacterium must be isolated from the diseased animal (or human) and grown in pure culture outside the body of the animal or person.
3. The pure culture must cause the same disease when introduced into the body of a normal animal (or human).
4. The same organism must be recovered from the experimental animal (or human) and grown again in pure culture.

By means of these rigid tests and by means of the remarkable immunology reactions described on later pages in this text, specific pathogenicities have been proved for a number of micro-organisms. Under these circumstances no open-minded person can deny the existence of pathogenic micro-organisms.

Description of pathogenic bacteria.—The pathogenic bacteria are the bacteria that cause disease. Our common colds, sore throats, attacks of bronchitis, are caused usually by pathogenic bacteria. Among the more common pathogenic bacteria are the bacillus of

typhoid fever, the pus coccus, the gonococcus, the diplococcus of meningitis, the bacillus of diphtheria, the bacillus of whooping-cough, and the bacillus of tuberculosis. All bacteria, pathogenic and non-pathogenic, commonly appear in one of three forms. The cocci are round, dot-like forms, such as the pus cocci that cause boils and abscesses. A coccus may be as small as one two-hundred-thousandth of an inch in diameter. The bacilli are longer rod-like

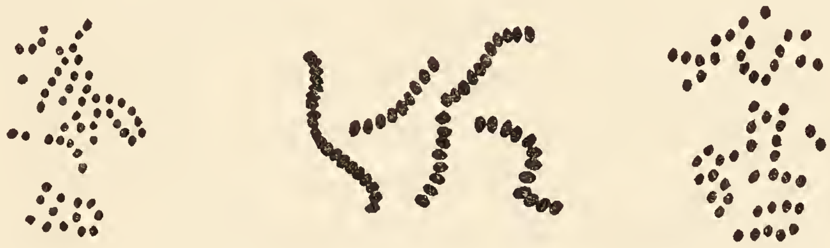


Fig. 56.—Types of micrococci (after Williams as described by Marshall).

Fig. 57.—Types of bacilli (after Williams as described by Marshall).

Fig. 58.—Types of spirilla (after Williams as described by Marshall).

forms, such as the bacilli of typhoid fever or tuberculosis. The tubercle bacilli average about one five-thousandth of an inch in length and one fifty-thousandth of an inch in diameter. The spirilla are curved forms, such as the spirillum of cholera. The spirilla are the largest of the bacteria.

Some bacteria are motile because of hair-like fringes (flagellae) attached to their sides or ends. The flagellae have a characteristic motion.

Some bacteria produce spores; others do not. A spore is a more resistant seed-like structure which the bacterium manufactures within its body, and later discharges from its body. The spore is usually roundish and much smaller than the bacterium from which it came. More will be said about spores later. Bac-

teria live in dark, damp, warm, and dirty places. They die in sunshine; drying kills most of them. They do not grow well in the cold. High temperatures destroy them.

Pathogenic bacteria reproduce best in the tissues or in the tissue juices of human beings and animals. Some pathogens will reproduce only in human beings. Many pathogenic bacteria will not grow in nature. Pathogenic bacteria may remain alive for hours, days, weeks, or even months in favorable surroundings outside the human or animal body. Some bacteria die more quickly than others under such circumstances. We find tubercle bacilli alive in human spit. If such sputum is left in dark, damp, and warm places, the bacilli in the sputum will live for a long while. Typhoid bacilli will live for a long while in cows' milk. If the milk is warm they will reproduce. Pathogenic bacteria are found in the normal human throat; between the teeth; in the nose; under the eyelids; under the nails; in the creases and pores of the skin; in the intestines; in the respiratory, intestinal, and genito-urinary secretions, excretions, and discharges.

Fig. 59.—Tetanus bacillus showing spores (after Kolle and Wassermann as described by Stitt).

The multiplication or reproduction of pathogenic bacteria (applies to all bacteria).—Bacteria reproduce rapidly. Each bacterium reproduces by separating into two parts. A bacillus divides trans-

versely so that two bacilli are formed, each about one-half as long as the original bacillus was. A coccus divides into two cocci; a spirillum into two spirilla. It takes a bacterium on the average about one-half hour to divide into two bacteria. Some divide in fifteen minutes; others take an hour. If a single bacterium could be unhindered in its multiplication, if all its descendants could double their number every half hour without restriction, it would be possible within a few months to increase that one single bacterium to such an enormous number as to occupy all the space of our universe, even to the limits of the circuit of Neptune.

We noted above that some bacteria produce spores. A spore is a "seed" which is capable of resisting influences which would destroy the bacterium which produced it. Spores are much smaller than the bacteria from which they come. A spore is much harder to destroy than the adult bacterium. It may lie a long time in a dormant condition. The spores of anthrax are said to have been found alive in the surface soil of a pasture after thirty years of quiescence. When its surroundings are favorable, when the temperature, the humidity, and food supply are favorable, the spore begins to grow and soon becomes an active bacterium which multiplies in the usual way by binary fission. There are, then, at least two sorts of bacterial reproduction—one by spore formation, and the other by simple division, probably mitosis.

The habitat of pathogenic bacteria.—The bacteria that cause disease in human beings grow (reproduce) best in the tissues of human beings and other warm-blooded animals. Some of these pathogens will reproduce only in the tissues of human beings.

The bacillus of anthrax is common cause of disease in sheep and cattle. It may also cause very serious disease in careless persons who handle infected animals, or their skins or wool. The bacillus of glanders frequently causes disease in horses and cattle. The men who handle such animals are often infected. The bacillus of bovine tuberculosis causes tuberculosis in cattle. Sometimes the disease is conveyed to children through milk infected by the bovine bacillus. The *Bacterium tularense* may infect wild rabbits, rats, cats, grouse, quail, sheep, and woodchucks, as well as man.

There is evidence that the bacillus of avian tuberculosis (tuberculosis of birds) does not commonly cause tuberculosis in other animals; and that the bacillus of reptilian tuberculosis does not commonly cause tuberculosis in animals that are not reptiles. There

are numerous other bacteria that will grow in animals but not in humans.

The tubercle bacillus that infects human beings will not infect any of the cold-blooded animals. It will cause disease in monkeys and various other warm-blooded animals. In 1932, in the area of registration, inclusive of Hawaii, there were reported 75,509 deaths from tuberculosis, all forms. The bacilli of typhoid and paratyphoid fevers caused the death of 4,441 people in the United States in 1932. The gonococcus makes more babies blind than any other cause. The spirillum of cholera has been kept out of the United States for some years. It has cost this country thousands of lives and millions of dollars. It is a common cause of disease in South America, in European and Oriental countries. The bacillus of diphtheria infects children by preference. It may also infect puppies, kittens, horses, and mice. There were 5,418 deaths from diphtheria in the area of registration (inclusive of Hawaii) in 1932.

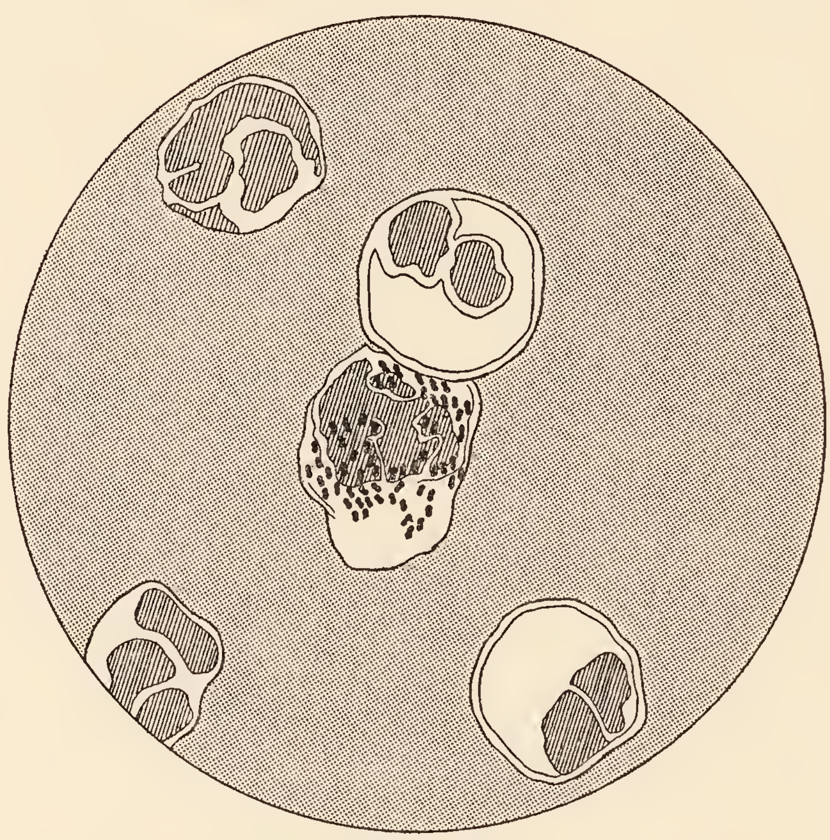


Fig. 60.—Gonococci and pus cells. The cocci are shown within the white blood corpuscle. (Enormously enlarged. After Williams as described by Marshall.)

Some pathogenic bacteria will grow in any of the human organs and tissues. Others seem to be limited to certain organs or tissues. The tubercle bacillus, the pus coccus, and the pneumococcus (the cause of lobar pneumonia) may grow anywhere

in the tissues. While the tubercle bacillus may grow in any of the organs, it grows most commonly in the lungs and bones. It grows least commonly in the muscles. The pneumococcus, in the same way, grows more commonly in the lungs. The bacillus of diphtheria grows oftener on the surface of the throat and the nose than anywhere else. The diplococcus of meningitis grows

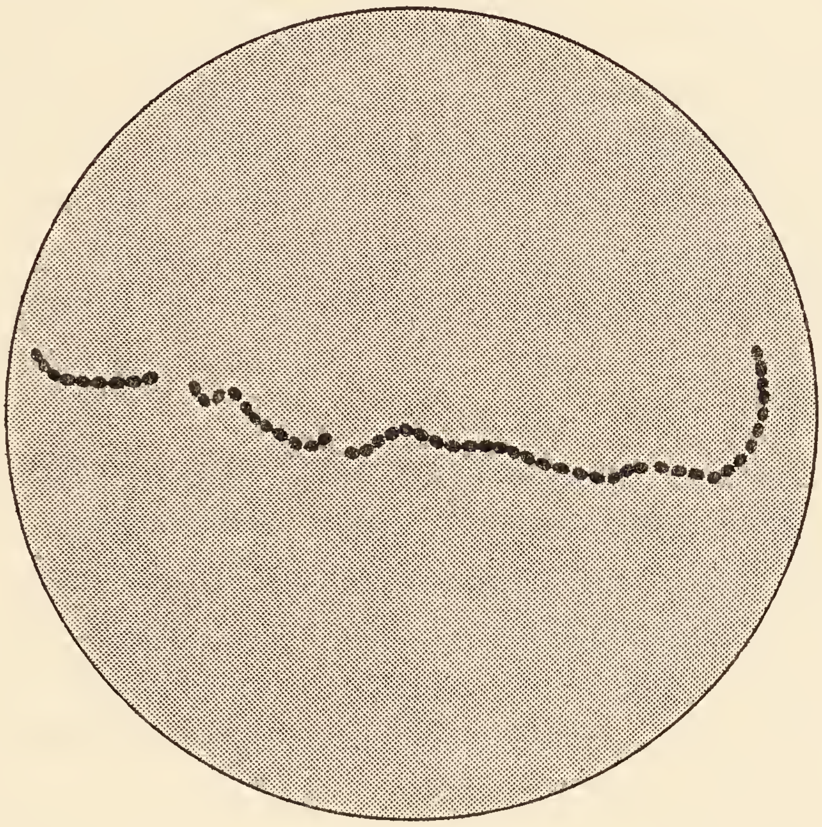


Fig. 61.—Streptococcus pyogenes (after Kolle and Wassermann as described by Stitt).

best in the membranes that cover the brain and spinal cord. Other pathogenic bacteria have their "preferences" for special tissues. These facts constitute one reason why we have diseases of different organs—as diseases of the lungs, or the brain, or the bones.

Avenues through which bacteria gain access to the tissues.—Normal healthy body tissues contain no bacteria. Most bacteria cannot pass through the normal skin. The bacillus-like *Bacterium tularense* is a notable exception. Many of them cannot pass through the normal mucous membranes. The mucous membranes line all the cavities of the body which are connected with the exterior. This includes the mouth, stomach, intestines, nose, eye, genito-urinary apparatus, etc.

Bacteria may enter the tissues through breaks, wounds, punctures, incisions, lacerations, abrasions, and other injured regions in the skin and the mucous membranes. These injuries may be

microscopic—a bacterium is small—a scratch of a pin, a scratch from a finger-nail, the rubbing of a rough collar or undershirt, the bite of an insect such as the head louse, flea, bedbug, fly, or mosquito—any of these may supply an opening for the entry of the pathogen. The congestion in the throat following exposure to cold or the wet may rupture small capillaries and provide an opening for bacteria. A blow on the chest, on the nose, or on the eye may give the same opportunity. Constipation may injure the mucous membrane of the intestine and supply an avenue of entry. Thus they may enter through the outer surface (skin) of the body, or, being inhaled, swallowed, or otherwise introduced into the respiratory, intestinal, genito-urinary, or other openings in the surface of the body, they may enter through breaks in the inner surface (mucous membrane) which lines those tracts, openings, and passages.

There are said to be fifty varieties of bacteria in the normal mouth; there are many bacteria under the eyelids, in the nose, in the decayed teeth, on the gums, and on the tonsils. The hair of the scalp and body harbors bacteria. The skin holds them in its pores and creases. They are found on the fingers and under the nails. Some of these bacteria may cause inflammations and disease if they are permitted to pass into the tissues.

Injury of any sort to the skin or mucous membrane may afford an avenue of entry for the bacteria that cause disease. This injury may be so small that it cannot be seen. Bacteria are always present waiting to get in.

Conditions modifying infection.—After having gained access to the tissues, further growth of bacteria depends upon several conditions. First: It depends upon the virulence of the bacterium. The same variety of bacteria may in one case be extremely virulent, that is, active and strong, and in another case attenuated, that is, weak and inactive. Second: Further development depends on the number of bacteria that get in. Within certain limitations our tissues will destroy all bacteria that reach them. Third: The avenue of infection has a marked influence. Thus, if the tubercle bacillus enters through the mucous membrane or is injected into the tissues, the usual serious result is probable. If, however, it enters into the skin, it may be destroyed or limited to the locality in the skin to which it found entry. Fourth: Some tissues destroy all the organisms of certain diseases that reach them. Fifth: The

healthy condition of the body determines its resistance. A normal healthy body will be less liable to infection by some pathogens than a less normal body. The fluids of a normal healthy body destroy some bacteria and neutralize their poisons. There are certain bacteria, however, that are not subject to these modifying conditions. Once in the tissues, they cause their specific diseases regardless of the conditions they find there.

The effects of pathogenic bacteria on human life.—After having established themselves in the tissues, pathogenic bacteria may cause injury in various ways. In nearly all infectious diseases the pathogenic causes are found at one time or another in the blood. They are then distributed by the blood to all parts of the body and may establish themselves in places that are specially favorable to their multiplication.

During the life of a great community of many billions of bacteria within the human body the following must take place: (1) These bacteria need food. They may destroy tissues and tissue products in order to satisfy their hunger. (2) Such bacteria manufacture secretions. (3) They must give off excretions. (4) They must form and give off waste products. (It is not possible to separate secretions, on the one hand, from excretions and waste products on the other, except in theory. We know that these several products exist but we cannot always separate them from each other.) (5) They die and their dead bodies are dissolved by the action of the tissue fluids. (6) From secretions, waste products, excretions, and dissolved dead bodies, numerous injurious chemical substances arise. There are known to be formed in this way various poisonous acids, bases, and salts, among which are a number of powerful toxic chemical substances of very great pathogenic importance. Some of these chemical bodies are known as "antigens." The toxin of the diphtheria bacillus is perhaps the best known bacterial poison. (7) All the products that go into solution are likely to be carried by the blood to all the tissue cells of the body. These floating chemicals irritate the tissue cells so they produce new "defensive" chemical bodies of their own. These chemical bodies are known generally as "antibodies." An "antigen" is a chemical body that causes the production of "antibodies."[1] (8) The chemical reactions between the products of

[1] Antigens and antibodies and their relations to immunity are discussed in a later chapter.

bacterial activity and the products of cellular activity may form new injurious chemical compounds.

During an infection by pathogenic bacteria we have, then, local mechanical injurious effects and local and general toxic (poisonous) chemical effects. And so we have, in these infections, aches and pains, headache, delirium, paralysis, unconsciousness, nausea, vomiting, chills, fever, rapid breathing, and rapid pulse. Some diseases leave us with blind eyes, deaf ears, crippled hearts, useless kidneys, stiff joints, or a damaged mind. Death is by no means the worst injury pathogenic bacteria may cause in man.

Final results of infection with pathogenic bacteria.—Some infections are notoriously fatal. (1) In Russia in 1892, 800,000 persons died of cholera. (2) In the area of registration in the United States 75,509 persons died of tuberculosis in 1932. (3)

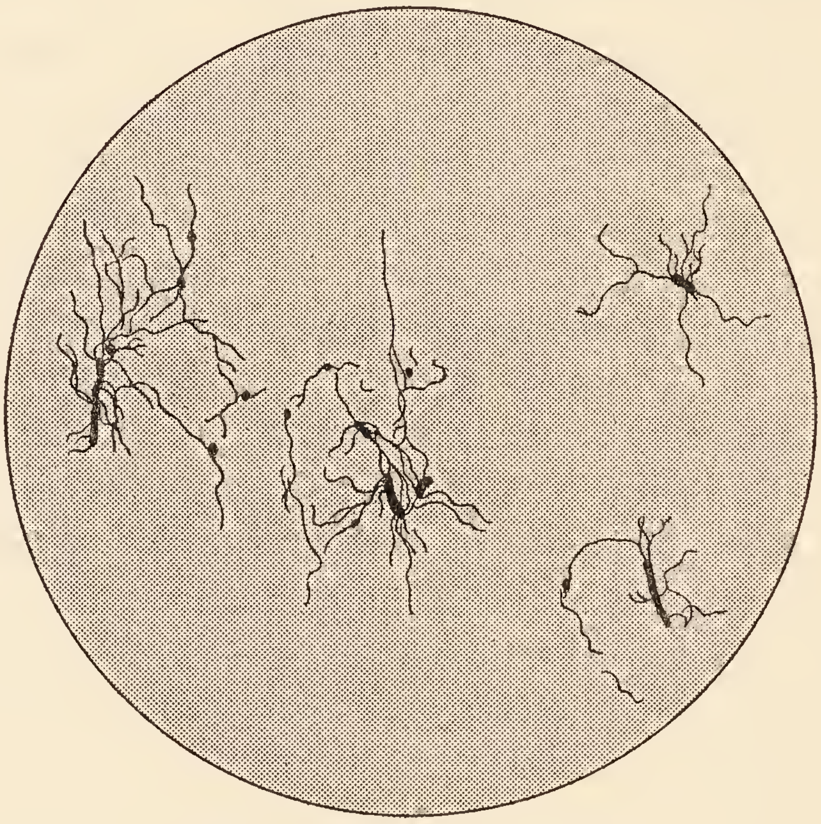


FIG. 62.—Bacillus of typhoid fever showing flagella (enormously magnified) (after Williams as described by Stitt).

We noted above that 4,441 people died of typhoid fever in the area of registration in 1932. (4) Over 7,500,000 human beings died of bubonic plague in India between 1890 and 1915. (5) At one time over forty per cent of children infected by the diphtheria bacillus died. Now, with treatment by antitoxin, the rate is less than nine per cent and with very early treatment the rate is much lower.

There are other serious bacterial diseases which might be

listed here. On the average about 450 persons die of infectious disease every day in the continental United States. The majority of these deaths are caused by bacterial infections.

A number of these infections leave the individual crippled in mind or body. Diphtheria may leave paralyzed nerves. Typhoid fever may leave bad kidneys or a weak heart; meningitis may leave blind eyes or deaf ears; gonorrhea often leaves sterility, blind eyes, or crippled joints.

The majority of persons in good health recover from their first attacks of infectious disease. These recoveries are due to the fact that the tissue cells of the human body have the power of manufacturing specific defenses against various infections (antibodies, etc.).

Exits of pathogenic bacteria from the human body.—During an attack of bacterial disease and sometimes for long periods after, the bacteria that caused the disease are expelled from the body in enormous numbers, by way of the various avenues of excretion. In fact, the several excretions always contain pathogenic organisms, even in health. The organisms that cause disease of the air passages are expelled largely by way of the nose and the mouth. Some of these organisms are swallowed and escape along with the intestinal excretions. The organisms that cause disease of the intestinal tract are expelled by way of the bowels. The organisms that cause disease of the genito-urinary tract are expelled by way of discharges from that tract.

The carriers of communicable disease.—Any agent that brings these pathogenic bacteria to human beings becomes thereby a carrier of disease. The source of nearly all human infection is the human carrier. Pathogenic bacteria may be transferred from one human being to another by direct contact. The most typical examples of infection by direct contact are found in the sexual transfer of venereal diseases. Pathogens may be transferred a little less directly through "droplet infection," that is, by way of the fine spray of mucus and saliva that accompanies coughing, sneezing, etc. The transfer may occur by way of infected food, water, and articles in common use. Several insects which feed and breed in human excretions or feed on human blood are known to be carriers, e.g., the mosquito, the fly, the louse, and the flea. Some animals may serve as carriers, e.g., the cat, the dog, the rat. We will discuss the carriers of pathogens in a later chapter.

The protozoa that injure health.—The protozoa are very small animals. Some of them are large enough to be seen by the naked eye, but most of them may be seen only with the help of a microscope. There is evidence that some of the disease organisms that are small enough to pass through the fine pores of porcelain bacteriological filters are protozoa.

The protozoa are simple one-celled animals. The bacteria are simple one-celled plants. All of the functions, all of the activities, all of the work of these animals are performed by the one cell of which each is made. In the higher animals the work of living is divided between the millions of specialized cells which, taken together, form the animal body. This is true of man. Thus, our muscle-cells do our heavy work; our nerve-cells do our feeling, seeing, smelling, tasting, directing, and thinking. A nerve-cell that assists in the complex function of seeing has no part in the function of smelling. Every cell is a specialist. But in the protozoa, the one microscopic cell does all the things that protozoa are able to do.

One of the most typical of the protozoa is the amoeba. Under the lower power microscope it looks like a dirty gray drop of water. When it eats, it flows around the food particle that happens to be in its way. It does not seem to have any particular mouth part. This curious way of eating is characteristic of amoebas. It is also characteristic of the white blood cells and certain other cells of the human body. When it excretes, the particles excreted seem to be thrown out anywhere through the surface of the amoeba. It travels very slowly by simply flowing along, much as a drop of water might if it could push out a tiny projection in any direction and then flow into the little projection. This curious way of moving about is called "amoeboid motion." It, too, is characteristic of the white blood cells and certain other cells of the human body. We will have more to say about these white cells at another time.

Fig. 63.—Endamoeba coli (from Doflein after Hartmann as described by Stitt).

The protozoa are not so uniformly alike as the bacteria are.

They are all one-celled but they differ in many ways. For these reasons it is hard to describe the protozoa. About seven thousand species of protozoa have been described.

The protozoa live in sea water, fresh water, damp soil, vegetable matter, and animal matter.

These organisms reproduce by simple division (mitosis), by sexual conjugation, and by spore formation. They multiply quite as rapidly as bacteria do.

Some forms of protozoa pass through certain stages of growth in regular sequence, so that from time to time the appearance of the protozoa changes most remarkably. This typical and regular sequence of changes in the case of any given protozoan is called the "life cycle" of that protozoan.

The life cycle of the malarial parasite, for instance, is made up of a cycle of development which includes a period of development in the red blood corpuscle of the human and a period of development in the stomach and salivary pouches of the mosquito. Other protozoa have even more complex cycles than this. A knowledge of these cycles is of great importance in our warfare against the protozoa that cause disease.

The pathogenic protozoa require special surroundings. These surroundings must be of the right temperature, moisture, and darkness and must contain the requisite food. So far as we know the protozoan of malaria will live nowhere else than in human blood and in the body of the mosquito; the trypanosome of sleeping sickness will live nowhere save in warm-blooded animals and certain biting, blood-sucking flies; the protozoan of syphilis only in humans and certain monkeys.

Protozoa are destroyed by drying, by high and low temperatures, by sunlight, and by any radical change in their natural environment.

Relation of protozoa to human health. — Protozoa are grouped into pathogenic protozoa and non-pathogenic protozoa. It is possible that under special conditions the pathogenic forms may become non-pathogenic, and the non-pathogenic, pathogenic.

The pathogenic protozoa.—*The malarial parasite.*—Malaria is caused by an animal parasite which is called the plasmodium of malaria. This plasmodium is so small that it can be sucked through the capillary bore of the proboscis of a mosquito—so small that hundreds of them may grow in the stomach of a mos-

quito; so small that hundreds of them may live in the salivary pouches of a mosquito waiting to be squirted into human tissues when the mosquito feeds on human beings. It is so small that it can enter the red blood corpuscle (there are 4,000,000 red blood corpuscles in a cubic millimeter of blood with plenty of room to spare) and multiply in the red corpuscle until there are a score or more of the young parasites produced in that single red cell. The parasite of human malaria grows only in the human being and in the anopheles mosquito. Without the mosquito, or the human, the parasite could not live. Malaria is a common disease. Malaria is never caused by anything else than the plasmodium of malaria. Malaria is transmitted through the mosquito. Without the mosquito there would be no malaria. The only mosquito that carries this parasite is the anopheles mosquito.

The trypanosomes form another important group of protozoa, some members of which cause serious disease. A disease caused by these organisms is called trypanosomiasis. Infections from different trypanosomes occur in South America, Africa, Southern Europe, Persia, India, Burma, China, and the Philippines. Many kinds of animals are affected as well as man. A typical trypanosome is a very small, elongated, flattish animal, looking, under the microscope, something like an eel. It has a flagellum or hair-like process on one end and a fin-like membrane extending from the flagellum along the whole length of the body. Its movements are very active. These organisms live and multiply in the blood of animals and man. Life cycles have been described for them. The only disease of human beings caused by these organisms is sleeping sickness or human trypanosomiasis. It is caused by a specific trypanosome which is called the *Trypanosoma gambiense*. The organism is carried from man to man or from animal to man by the tsetse fly, and perhaps other blood-sucking flies. Up to the present time they have been found alive only in the blood of human beings and some animals, and in the stomach and sucking apparatus of the tsetse fly. This disease is limited to the regions occupied by these flies, which limitation at the present time confines the disease to parts of Africa. Here the disease is a terrible scourge and produces a most serious and fatal sickness. The disease has been reported in South America.

The amoeba is another protozoan, some forms of which cause disease. Amoebic dysentery has been found more or less all over

the world, particularly in tropical and sub-tropical countries. The amoeba is a microscopic organism of very considerable biological interest. It is described rather inadequately in the earlier part of this chapter. The chief carrier of this organism is drinking water which has been contaminated by the excretions of persons or animals sick with the disease. The disease itself is very uncomfortable and painful. Many patients die.

The Spirochaeta pallida, or the Treponema pallidum, is probably a protozoan. This spirochaeta is very small, but is larger than the average bacterium. It is long and slender, shaped like a thread,

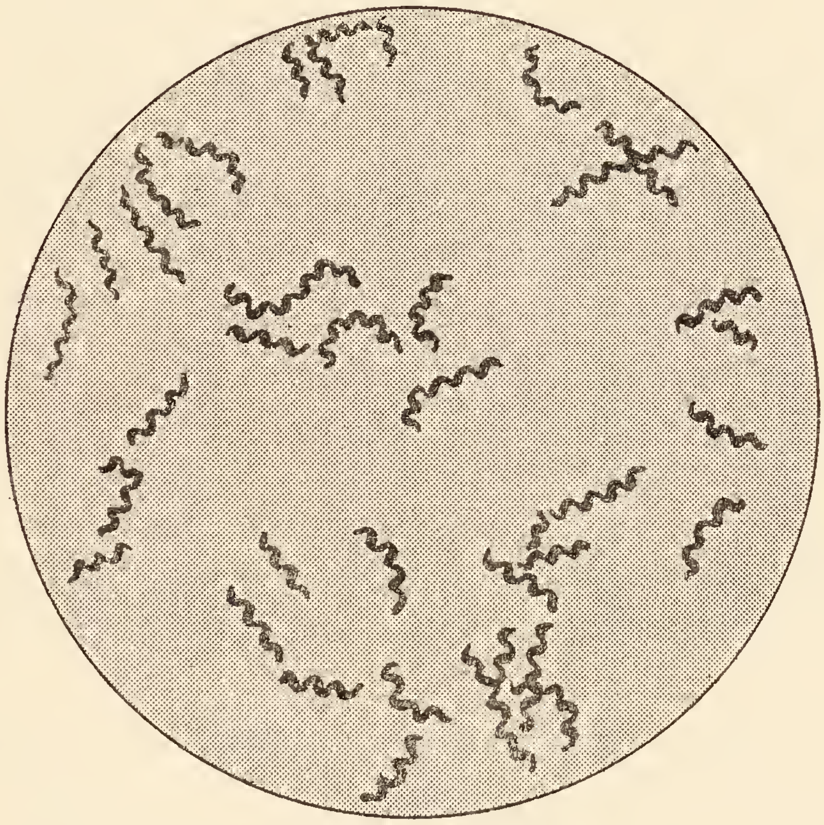


Fig. 64.—Treponema pallidum (after Kendle as described by Appleton).

though somewhat broader. It has a curious spiral movement. The Spirochaeta pallida or Treponema pallidum is found in the blood, tissue juices, secretions, and sores of syphilitic victims. It is the cause of syphilis, discovered in 1905 by Schaudin and Hoffman. This organism is transmitted by intimate contact as in sexual intercourse, drinking from contaminated cups, eating with contaminated spoons, smoking the pipe of a syphilitic individual, etc. Syphilis is always derived from some one who has the disease. It may come through some innocent medium—a cup, a pipe, a drink, a kiss. It has destroyed more children, crippled more men

and women, ruined more homes than you can imagine. It is one of the most common and most serious diseases of civil life, and in military life it sometimes does more damage than the weapons of war. It is most frequently secured through illicit sexual intercourse but may be spread by contact from husband to innocent child; from guilty brother to innocent sister, mother, or friend. There were 10,864 deaths from syphilis in the registration area in 1932.

CHAPTER XXX

THE PATHOGENIC METAZOA, OR THE MULTICELLULAR ANIMAL PARASITES THAT CAUSE DISEASE

Parasites.—This group of agents that cause disease includes a number of higher animal parasites, their eggs, embryos, and larvae. The more important members of the group are the flukes, tapeworms and their larvae (bladder worms), hookworms, and other round worms.

The frequency of parasites.—There is no species of animal and no race or class of men known to be free from parasites (Stiles).

Influence of parasites upon their hosts.—The injury done may vary with species, size, location, and the number of parasites and with the condition and age of the host. This injury may be accomplished in various ways: Nourishment is taken which should go to the host; blood is taken by the parasite for food; mechanical pressure irritates or causes atrophy of organs or parts of organs; natural channels may be obstructed; the wandering of the parasite may cause irritation; substances may be excreted which have a toxic influence and which may change the condition of the body fluids; injury to the intestinal mucosa or to the skin may form points of entrance for bacterial and protozoan infections.

Trichinae.—The adult worm lives in the upper part of the intestine. The male is 1.4 to 1.6 millimeters long and 40 microns in diameter.[1] The female is 3 to 4 millimeters long and 60 microns thick.

The female lives in the lumen of the intestine or bores into its walls and deposits her young during a period of five or seven weeks. Each female produces about 1,500 embryos in that length of time. These embryos are considerably smaller than the adult organism. They wander with the lymph or blood to the striated muscles. Here they locate and develop into "encysted larvae" or, as they are commonly called, "flesh worms."

These encysted larvae remain alive and lie curled up in the

[1] A micron (or a μ) is the millionth part of a meter; or 1/25,400 of an English inch.

muscle for years. This larval stage is the infective stage. When meat containing larvae is eaten, the cysts are destroyed in the stomach and the larvae pass into the small intestine and develop there into adult forms.

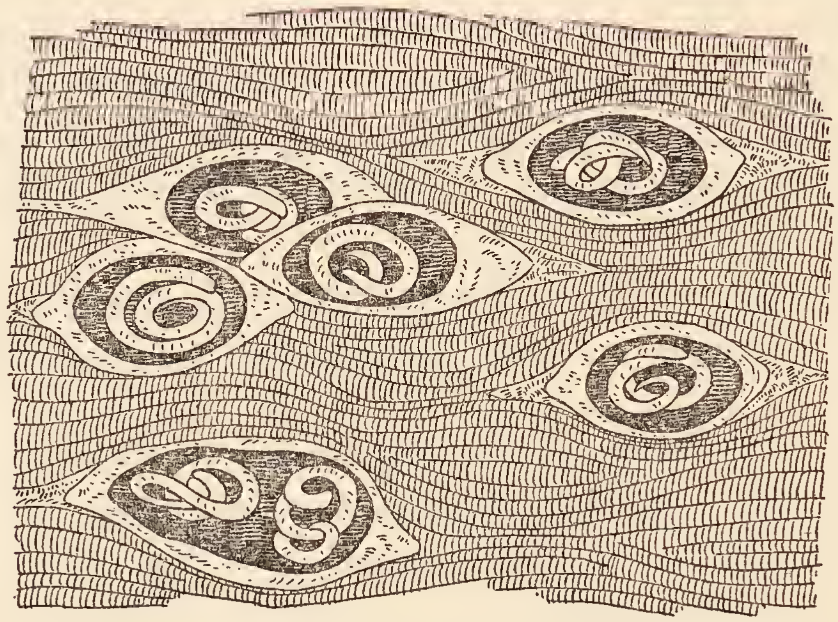


FIG. 65.—Trichinella spiralis (after Ziegler as described by Stitt).

Carriers of trichinae.—Humans, hogs, wild boars, rats, dogs, and cats are affected by the disease and contain the encysted larvae in their tissues. The uncooked flesh of hogs may carry the disease to human beings who eat it. The flesh of hogs, rats, dogs, and cats disseminates the disease among them.

The disease of trichinosis is always uncomfortable, frequently serious, and occasionally fatal. It is not a common disease. A small outbreak of trichinosis occurred in the Borough of Queens, New York City, in February, 1916. Twelve persons were treated at St. Joseph's Hospital. In spite of the best of care four of the patients died. Early in the year 1924, nineteen cases of trichinosis were reported in the state of New York with three deaths.

Pork should always be thoroughly cooked before eating. It should be subjected to a temperature of at least 160 degrees Fahrenheit.

Tapeworms that cause disease.—Man becomes afflicted with tapeworms by eating flesh of insufficiently cooked beef, pork, or fish containing encysted larvae of the parasite or by eating food that has been contaminated by the excretions of infected dogs, cats, rats, mice, or by transferring the eggs directly to his mouth on his fingers.

Some tapeworms grow as long as thirty feet. Others are only a few millimeters in length. They grow in segments and are flattened. The head end contains suckers, and in some forms is armed with hooks.

Tapeworm disease is caused by eating the larvae of tapeworms in insufficiently cooked beef, pork, and fish. Tapeworms of less common occurrence may be secured from dogs and rats by hand-

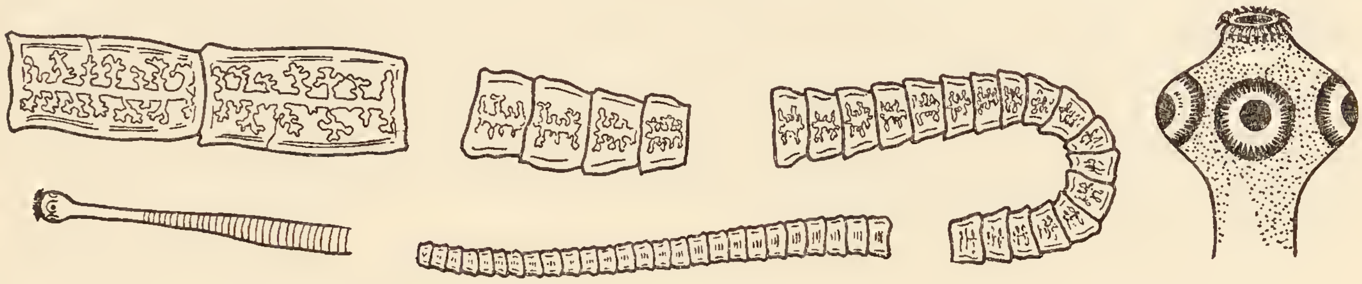


Fig. 66.—Tapeworm, Taenia solium (after Stitt).

ling them and transferring the eggs on the fingers to the mouth or by eating food they have contaminated. One tapeworm is liable to lay 150,000,000 eggs a year, so that the chance of spreading the disease is not to be underestimated. People who carry tapeworms are usually starved. They lose weight, become thin, emaciated, and if unrelieved, may die. Tapeworm disease may be avoided by eating no raw or insufficiently cooked meat.

The hookworm.—This is an animal parasite of about the size and shape of a slightly bent pin. There are two well-known hookworms—the Old World hookworm and the New World hookworm. They are very much alike. The young hookworm develops from eggs that have been cast out in the fecal discharges of human beings sick with hookworms. These eggs hatch if they chance to be left in warm, moist surroundings. After a few weeks the young hookworm is ready to attach itself to its human victim. If the young worm happens to have developed in dejections that were cast in or near a vegetable garden it may be carried to the table in green food such as celery, radishes, lettuce, and the like. If a bare-footed human walks through the grass in which there are young hookworms, the little worms may get on his feet, bore through the skin, and thus find their way by a devious route through the blood stream, the lungs, and the gullet to the intestinal canal. The adult life of the hookworm that is picked up by the human is spent in the intestinal canal of that human. Here the worm fastens itself by means of its sharp teeth into the in-

testinal wall. It sucks the blood of its provident host and poisons him with its toxic excretions.

The great majority of our Southern farms have no privies. Also the great majority of our Southern country folks go barefooted. Many of our Southern country people are not careful in their habits of hygiene. And so the great majority of our Southern rural population have hookworms. The hookworm belt reaches from 30 degrees south latitude to 36 degrees north latitude and goes around the world. It holds several hundred million persons affected with hookworm. Those people are injured physically, mentally, and morally. They are educationally and economically depressed or paralyzed.

Whenever people suffering with hookworm are persuaded to undergo treatment and to practice habits of good hygiene, their disease disappears, and they often become wide-awake, useful citizens. The Rockefeller Foundation has proven the value of hygiene most dramatically in the hookworm sections of our Southern states, and in all the countries of the world in which hookworm occurs.

CHAPTER XXXI

CONCERNING CERTAIN DISEASES THE CAUSES OF WHICH ARE UNKNOWN

Causes of cancer.—Cancer is a disease of middle life and later life. One man in every ten and one woman in every seven past the age of forty-five, in the United States, dies of cancer. It is one of the most hopeless of all the diseases of mankind. Practically every advanced case has resulted in the death of the patient. There were 122,739 deaths from cancer reported from the area of registration in the United States in 1932. But if treated very early, cancer can be prevented or even cured.

The cause of cancer is not known.

Chronic irritations often pass into cancer. Chronic ulcerations, irritated scars, moles, warts, benign tumors, and other irritations of long standing are called precancerous conditions because they frequently develop into cancer. We do not know why.

Cancer may be produced in some of the lower animals by inoculating them with cancerous tissue from other animals.

Cancer has been produced in rats that have been fed with cockroaches in which certain intestinal parasites were present.

Cancer in mice is more likely to reappear in mouse families in which it has already appeared. We have no proof that human cancer is inherited.

Fish and dogs have developed cancer when fed on scrapings from aquaria in which fish with cancer had been living.

Cancer-like growths are found on trees.

Sarcoma, a malignant growth similar to cancer, has been produced in chickens by inoculating them with a filtered emulsion of sarcomatous material taken from other chickens.

Such experiments will undoubtedly enable us to discover the cause and the cure for cancer and other malignant growths.

Prevention of cancer.—The following quotation dealing with the prevention of cancer is taken from a publication of the American Society for the Control of Cancer.[1]

When we state that we do not know all the causes of cancer, we mean that we do not yet know exactly what makes a small cell or group of cells

[1] *What Every One Should Know about Cancer,* American Society for the Control of Cancer, 1250 Sixth Avenue, New York City.

change their nature and take on the extraordinary power of growth that is the fundamental characteristic of this disease.

A great deal is known about the circumstances attending these new growths, when and where they take place, and what conditions favor the process; and much of the information is of distinctly practical value. Even though we do not know all the causes of cancer, we do know a good deal about how it occurs and what conditions are apt to precede it. By avoiding or correcting these conditions, we can prevent cancer.

For instance, cancer frequently begins in moles or pigmented warts which are irritated by the clothes, or are made to bleed and kept sore by repeated injury. Such warts and moles are perfectly harmless at first. They become dangerous only after they have been irritated in some way for a long time, especially if the person is of the cancer age—that is, above thirty-five. It is wise to have such moles or warts removed, if located where they may be rubbed or injured.

It has also been found that cancer frequently develops in the scar of an old burn, or in a place where there is a chronic ulcer, as on the lip, tongue, or leg. Care should be taken to see that such ulcers are healed as quickly as possible.

Ulcers on the tongue and cheek frequently result from a scratch from a poor filling or from the sharp point of a decayed tooth. A dentist should be consulted if such an ulcer does not heal within a few days, in order that the filling may receive proper attention or the point of the tooth be filed off.

Cancers of the uterus often begin at the site of an injury resulting from childbirth. Consequently, all such injuries should be repaired as a measure of protection against cancer.

It is not improbable that cancer of the stomach may be brought about by the frequent consumption of highly irritating substances, as condiments, alcoholic liquor, and excessively hot and cold beverages. These should be used in moderation, or not at all, if cancer of the stomach is to be avoided. It is important for any one who has any disturbance of the stomach or intestines which cannot be promptly and satisfactorily accounted for, especially if there is loss of weight or anemia, to go at once to a surgeon, because by modern chemical methods, and by the use of X-ray photographs, a diagnosis can often be made. Cancers of the stomach often arise from neglected ulcers, from which it follows that by giving proper attention to the cure of the ulcer the formation of a cancer may be avoided.

It has long been known that irritating substances, such as soot, tar, crude petroleum, and certain of the chemicals used in making aniline dyes, may set up a chronic inflammation which may lead to cancer. Workers in these products should promptly consult a physician if any such trouble appears.

Smokers should be particularly careful about any sore on the lip or tongue. Such sores are commonly found in persons who use a pipe in such a way that the tongue or lips are chronically irritated by the hot stem, or who hold cigars in such a manner that the hot smoke continually strikes one spot. For this reason, cancer of the lip and tongue is very common in men, and is almost never seen in women.

All the irritants which have just been mentioned do not always cause cancer, but they give the cancer a chance to begin. If a man past middle life does not smoke heavily, cares for his teeth, and keeps his mouth clean, he is much less likely to have cancer of the mouth, lips, or tongue than one who does not follow this course.

Cancer of the lower bowel is frequently preceded by chronic inflammation. Therefore, persons who think they have chronic indigestion, dysentery, ulceration of the bowel, or bleeding piles should consult a physician in order to make sure whether their symptoms may not be due to beginning cancer.

Any woman who notices a lump in the breast should at once consult a physician. In most cases she will be told that the lump is harmless and need not be removed. And it is much better to be told that it is an early and curable cancer than to wait until the disease is too far advanced to be eradicated.

It is a good plan to have a thorough physical examination made by a competent physician once a year. Many early and unsuspected cancers have thus been discovered, and conditions which may lead to cancer can then be found and steps be taken to prevent the cancer from beginning.

Cancer attacks not only persons who are in feeble health, but also, and with equal frequency, those who are strong and healthy, and have never suffered from any other serious disease. For this reason, it is quite as important that healthy people consult a physician if any sudden change in their well-being takes place, as it is that any one else should do so.

The opinion which has been reached by some of the foremost statisticians of the United States is that cancer is slowly increasing in this country. Unquestionably, it is one of the most important causes of death among people of thirty-five years and over.

The public is ignorant of the symptoms and not aware of the necessity for early treatment. Because of this lack of knowledge, relatively few patients go to a physician in time for satisfactory treatment.

As cancer is not a germ disease and is not contagious, but is an abnormal growth of cells in the body, it cannot be suppressed by public health measures such, for example, as have so greatly diminished typhoid fever and tuberculosis.

Medicines taken internally have no value. No serum is known which, when injected, will cure cancer.

Neither pastes, plasters, nor other non-operative methods, so widely advertised by quacks, are effective methods for the treatment of cancer. The favorable results, reported in the newspapers and in the advertising material and testimonials of charlatans, are generally obtained with ulcerating growths which are not cancerous. There is no question that some cancers can be destroyed by caustics; but much of the normal tissue about the cancer is also eaten away. The caustic is less easy to control in its action and much less certain than the removal of the cancer by the knife.

Radium and X-rays have been much used of late in the treatment of cancers of the skin, and have been found to be of great value in certain types of the disease.

Other cancers are very difficult to cure by radiation, even when it is used in large quantity. When a skin cancer has grown into near-by bone or cartilage, or has spread through previous ineffectual treatment by caustics, or when the growth is complicated with syphilis or tuberculosis, the results are unsatisfactory.

Cancers of the tongue, lip, mouth, and especially those of the womb, have been treated by radiation with success; but it is still the general opinion of those who work with radium that, for the present at least, all cases of dangerous or malignant tumors which can be successfully removed by surgical operation should be so treated, radiation being reserved for such cancers as are beyond the reach of surgery.

Deep-seated cancers, such as those of the breast, lung, stomach, abdomen, intestinal tract, and bladder, are usually beyond the effective reach of radium, but often much improvement can be obtained by carefully adjusted applications of X-rays.

The proper use of radium requires large experience and great skill, if serious burns are to be avoided. As a rule, large quantities must be employed. Not every physician has a sufficient amount with which properly to treat cancer. X-rays have much the same effect on cancer that radium has. Suitable apparatus for the production of X-rays is not very expensive, so that if radium is not available X-rays may very properly be used in treating those types of cancer which are favorably influenced by radium. It is not always possible to use X-rays effectively in cases of internal cancer, since it is difficult to get a sufficient quantity of the X-rays to penetrate to the organs which are affected.

In superficial cancers, when radium is not available, the X-rays should be used. Their use, soon after incomplete or palliative operations, often temporarily checks the growth and greatly prolongs life and comfort.

Every one should remember that cancer begins as a small growth and that if it could be removed a short time after it appears it would always be curable. As the symptoms are not always characteristic, but are often obscure, it is necessary to consult a good physician at the earliest possible moment when the presence of cancer is suspected. One should not delay or apply home remedies in the hope that the trouble is of no importance.

In so far as the conditions which precede cancer can be avoided or removed, cancer is preventable. Briefly, irritation in some form is frequently an underlying or contributing cause; and since this can generally be stopped, a field has been opened for preventive work of a most valuable character.

Other diseases of unknown causes.—We do not know the causes of the following diseases: smallpox, chicken-pox, measles, mumps, trachoma, and break-bone fever. There are other diseases in this group.

Our ignorance concerning the causes of these diseases may be due to: (*a*) Lack of technique. Our knowledge of micro-organisms depends upon our ability to bring them into view, cultivate

them, and experiment with them. We must isolate a disease cause before we can make a study of it. (*b*) Many of these causes are too small to be seen with the power of magnification now at our disposal. A study of filterable viruses began in 1898. We know that the causes of the following human and animal diseases are so small that they will pass through bacteriological filters. We call such organisms "filterable viruses," "ultramicroscopic viruses," or "filtrate viruses."

Filtrate virus diseases of domestic animals: Pleuropneumonia of cattle, African horse sickness, sheep-pox, cattle plague, hog cholera, swamp fever of horses, infectious agalactia (sheep and goat), catarrhal fever of sheep, distemper of dogs, infectious stomatitis papulosa of cattle, guinea pig epizoötic, a peculiar paralysis of guinea pigs, and a rat disease.

Filtrate virus diseases common to man and animals: Foot and mouth disease, rabies, vaccinia, and smallpox.

Filtrate virus diseases of man: Molluscum contagiosum, dengue fever, verruca vulgaris, trachoma, sand-fly or three-day fever, poliomyelitis, typhus fever, trench fever, and measles.

Filtrate virus diseases of birds: Fowl pest, fowl diphtheria, chicken sarcoma.

We know very little about these minute causes of disease, but our knowledge is on the increase. At present we know (1) that some of these diseases are carried by biting insects, such as the mosquito, the fly, the louse, and the tick; (2) that others are introduced through grosser injuries as in rabies, a disease that is transmitted by the bite of an animal sick with rabies (hydrophobia); (3) that some of these diseases are transmitted by contact; (4) that all of these disease causes are destroyed by high temperature, some of them more easily than pathogenic bacteria; (5) that some of them are more resistant to drying than bacteria are; (6) that they resist cold; (7) that a few have been cultivated in the laboratory; (8) that the extreme minuteness of some of these disease causes, combined with their resistance to drying, may account for their contagiousness. "Minute particles suspended in air or in liquid obey the laws which govern the diffusion of gases and substances in solution in liquids." If these minute organisms were to obey the laws which govern the diffusion of gases and substances in solution then dissemination might take place under the influence of such law.

CHAPTER XXXII

INFECTION, ITS CAUSES AND EFFECTS, ITS DIAGNOSIS, TREATMENT, AND PREVENTION

The cause.—All infections are caused by living organisms, the most important of which in the light of our present knowledge are the pathogenic bacteria, the pathogenic protozoa, and the filtrate viruses. These organisms cause such infections as a cold, tonsillitis, Vincent's angina, trench mouth, sinus disease, bronchitis, gonorrhea, syphilis, infantile paralysis, scarlet fever, diphtheria, smallpox, mumps, whooping cough, and malaria.

The incubation period.—There is always a period of time between the moment of exposure described above and the appearance of symptoms and signs of disease. The length of this period is determined by the time it takes the invading pathogenic organisms to reproduce themselves in sufficient numbers to produce irritating effects on the host. The length of the incubation period varies with different kinds of pathogens, but the period is typical of each kind. For lobar pneumonia, it is from two to three days; influenza, two or three days; typhoid fever, seven to twenty-three days, but usually ten to fourteen; syphilis, about three weeks, but cases are on record in which the incubation period has lasted seventy days; gonorrhea, one to eight days, but usually three to five; suppuration and sepsis, from less than twenty-four hours to three days.

The exposure.—Infectious diseases occur as a result of exposure to the carriers of the organisms that cause those diseases. This may be accomplished by swallowing food or water that contains pathogens. The organisms may be inhaled. They may be transferred by contact with a carrier. They may be transferred from the fingers to the mouth. They may be rubbed into a raw surface, a wound, or a pin-point scratch. These pathogens may come from infected excretions, directly or by way of a secondary carrier; infected discharges from boils, abscesses, wounds, or other areas of local infection; blood transfers from infected persons or animals by blood-sucking insects, bites, or accidents of surgery.

The attack.—The colony of pathogens growing in the tissues may soon number many millions, each one of which may contrib-

ute a microscopic amount of chemical poison to its host, i.e., to the infected person or animal. The size of the colony, its irritating relation to vital organs, its destruction of tissue, and the chemical toxins it produces, the distribution of those toxins by the blood, all together cause signs and symptoms which are characteristic of the disease. There may be one or more of the following: (*a*) feelings of weakness, dizziness, nausea, chilliness, or there may be a pronounced chill with a lowered bodily temperature; (*b*) vomiting and diarrhea; (*c*) cough; (*d*) pain—local or general, or in joints and bones; (*e*) temperature, up; (*f*) pulse, up; (*g*) respiration, up with lung infections.

Progress of the infection.—The signs and symptoms may become more marked. The heart may tire. Paralysis may occur because of the poisoning of nerve-cells by the chemical compounds produced by the invading pathogens. New colonies of the pathogens may be produced by distributions in the blood and lymph to other organs. Thus a pneumonia in one lung may be followed by a pneumonia transplanted to the other lung; tonsillitis is sometimes followed by infection of the heart; gonorrhea is frequently transferred to the joints. These examples could be multiplied.

Final effect of an infection.—After a week or more in some diseases, three weeks or more in others, the signs and symptoms may disappear, the individual may gradually recover his strength and weight. He may be restored to good health.

Or he may have some permanent damage such as (1) injured heart valves; (2) degenerated kidney cells; (3) paralyzed nerves with consequent useless arm or leg, blind eyes, damaged hearing.

Or his infection may become chronic as middle ear disease, syphilis, or gonorrhea. Syphilis may lead to paralysis, damaged heart, or to insanity, years after the beginning of the attack. Gonorrhea is more difficult of cure than syphilis.

Or he may die in a few hours or a few days.

Diagnosis of infections.—Infections are diagnosed by signs and symptoms. For a time, the signs and symptoms may be much alike in a number of infections. After a time, certain signs and symptoms characterize certain diseases. Only an expert physician can decide. The diagnosis may sometimes be made by finding the specific organisms in the blood, the excretions, or the discharges, or by testing the reactions of the blood.

Treatment.—Rational treatment is made possible by a knowl-

edge of the organisms involved and the agencies that oppose or destroy them or neutralize their effect. Wise treatment is available only from men or women who have secured the best medical education and medical training that society provides.

Prevention.—Rational prevention is made possible by our scientific knowledge of pathogens, their carriers, and their enemies. This knowledge has enabled our medical, public health, and engineering experts to control yellow fever, typhoid fever, smallpox, typhus fever, cholera, tuberculosis, diphtheria, malaria, and bubonic plague. With the knowledge we now have we could control syphilis, gonorrhea, and various other diseases if that knowledge were put in general use.

Summary.—A typical infection presents an incubation period which may or may not be accompanied by signs or symptoms; an attack which may be sudden and severe, or gradual and insidious, but usually with final characteristic signs and symptoms; a course lasting days or weeks or even longer; and a termination either in recovery, disability, or death, depending in large measure on the competency of the scientifically prepared physician in charge of the case.

Scientific research methods have given us accurate information with which we have been able to prove that certain organisms are pathogenic to humans. Scientific research has shown us how they are passed from one human to another; what they do to humans; and how to defend ourselves against them.

There is much yet to be learned about a number of these enemies of human life and human health. Our additional knowledge will come only by way of patient, painstaking, scientific research. But the men who find the truth about an infection or other disease contribute precious facts that become the safeguarding equipment of mankind for all time to come.

CHAPTER XXXIII

DEFENSES AGAINST PATHOGENIC MICROBES

Our steadily increasing knowledge of the micro-organisms that cause disease and of the carriers of those organisms has furnished us with information concerning various natural agents that protect us against those organisms and their carriers. These defensive agents have acted for the conservation of human life unaffected by our ignorance through all the ages. These natural defenses exist in our environment or in the surface of the human body or in the cells of the bodily tissues. Modern science has amassed information concerning the influences that damage and destroy health; has accumulated facts relating to those natural agents that destroy or interfere with the causes and carriers of disease; and from these sources modern society is organizing rational scientific systems of defensive, individual, group, and intergroup hygiene for the conservation of human life.

We have then a growing knowledge of the natural agents that protect us from disease and we are more and more commonly utilizing, directing, and co-ordinating those agents for the more effective defense of human life.

The various organisms that cause disease and the various agents that carry disease are present all about us. Man in health and in disease expels myriads of pathogens by way of his respiratory, fecal, genito-urinary, and other excretions and discharges. One human being sick with tuberculosis may expectorate billions of tubercle bacilli in a single day, enough, if evenly distributed, to infect the entire human race. There are always many hundreds of thousands of persons sick with some communicable disease or other in the United States, and each one is more or less constantly discharging his many billions of pathogens.

Every one of those pathogenic organisms, under favorable conditions, is capable of enormous increase in numbers. A single bacterium, if left alone, if not restricted in its natural tendency to multiply by simple division, would within a few days produce enough bacteria to equal the bulk of the earth. A single tapeworm may produce 150,000,000 eggs in a year. Evidently there are some very effective reasons why these many varieties of disease-causing organisms have not destroyed the human race and cov-

ered the universe. Those reasons constitute our natural external defenses against disease.

Our natural external defenses against pathogens.—*Sunlight.*—The light and heat of the sun destroy most pathogenic organisms rapidly. The bacillus of tuberculosis present in the sputum may live in sunlight for twenty hours or more. The amount of time it takes sunlight to destroy bacteria varies under different conditions. The important point for us to remember is that this bactericidal action of sunlight takes time. Furthermore, the spores of some bacteria resist sunlight for a long time. We have noted elsewhere that the spores of the bacillus of anthrax have been found capable of growth after exposure for thirty years in the surface soil of a pasture.

Drying is another influence that destroys most pathogens rapidly. The bacteria that cause boils and abscesses are fairly resistant. The cause of infantile paralysis is resistant. Tubercle bacilli in sputum and diphtheria bacilli in membrane expelled from the throat may live for a long time, provided they do not dry out. The larvae of the hookworm will live for weeks in moist, warm grass, green vegetables, or soil, but they die very quickly if their surroundings are dry.

Low temperatures are not favorable to pathogenic growth and freezing destroys most but not all such organisms. The bacilli of typhoid fever have been recovered from ice.

High temperatures destroy all pathogens, even spores, but the temperatures in nature are never high enough to accomplish this result effectively. We use heat as a germicide. In nature, the combination of sunlight, sunheat, and fresh air is destructive to pathogens, and, in time, to most of their spores.

Lack of favorable environment.—The life of bacteria and other pathogens depends upon darkness, moisture, warmth, and appropriate food. The heat and light of the sun are continually making conditions unfavorable for such life. In addition, other factors which we do not understand are at work making it impossible for most pathogens to live long or reproduce themselves outside the human body. There are a few, however, that do live in nature, either in adult form or larvae form or as spores, and there are some that reproduce in nature and multiply, but in every case nature must supply a particularly favorable environment or the organism will not continue to live. It may truly be said that

for most pathogenic organisms the only perfect environment is found in the human or animal body or in the bacteriological laboratory.

The surface defenses of the human body.—*The skin.*—We know that very few disease organisms can gain access to the tissues through the normal healthy skin. Pathogenic organisms can enter only through scratches, punctures, or other destructive wounds. The young hookworm is a noteworthy exception.

The mucous membranes.—Many organisms live and produce upon the warm, moist mucous surfaces of the alimentary canal, the respiratory canal, and other natural openings, and channels of the human body connected with the exterior. But it seems to be true that most of those organisms are unable to pass through the mucous membranes unless some injury has occurred to make an opening through which they can enter. For example, the mouth-breather, the child or man with nasal obstruction, chronic nasal catarrh, adenoids, or large tonsils, is permitting injuries to the lining of his air passages so that disease organisms may more easily enter. In this way dirty gums, sore gums, and decayed teeth help pathogenic organisms in their battle against health. Constipation and indigestion make microscopic openings in the intestinal wall through which pathogenic organisms may pass.

The natural secretions.—The glands of the eyes secrete a fluid, the tears, which is continually washing the surface of the eyes and is carried away through a canal into the nostrils. The secretions of the nose, throat, and lungs mechanically exercise a cleansing effect upon these mucous walls. We excrete this material when we expectorate. The secretions of the eyes, the nose, the mouth, and the throat have a mildly antiseptic action. The gastric juice has a somewhat stronger antiseptic influence.

Ciliary movement.—The passages of the nose, throat, and larger air passages are covered with small hairs which filter the inhaled air, and which at the same time, gently and slowly but unceasingly, push the moisture, the excretions, the foreign bodies, and germs on and out of the respiratory tract. This ciliary action is present in other parts of the body.

The internal defenses of the body.—While the germs of the disease are on the skin or on the mucous membrane of the eyes, the respiratory or the digestive tracts, they are really outside the human body. If they gain access to the tissues through in-

juries of the skin or the mucous membranes, there are still other agents present within the tissues themselves that are active in defense against disease. The most important of these defenses may be described as follows:

The phagocytes.—(*a*) They are principally the white blood corpuscles. The action of these cells may be observed under the microscope. Such observation shows that one of these cells will ingest one or several bacteria and slowly dissolve them. This action is known as phagocytosis. These white blood cells are phagocytes. Under normal conditions there are between 5,000 and 8,000 white blood corpuscles in a single cubic millimeter of human blood. In some diseases this number is very greatly increased, and there may then be 40,000 or 50,000 or more, rarely over 100,000 per cubic millimeter. This increase in the number of white cells is known as leucocytosis. (*b*) There are other circulating cells of the body which have this phagocytic action. The significance of phagocytosis as a defense against disease is obvious.

Bacteriolysis (destructive action of blood serum and tissue fluids upon bacteria).—When typhoid bacilli are placed in normal human blood serum and observed under the microscope, it is soon noted that the bacilli gradually dissolve. This process is called bacteriolysis. Human blood has a bacteriolytic effect upon the typhoid, anthrax, colon, dysentery, cholera, and probably other bacteria.

Phagocytosis and bacteriolysis are processes by means of which the tissues of the body may destroy bacteria and thus protect themselves from disease.

Inflammation as a defense against disease.—When a number of bacteria gain access to the tissues at any given point, there is normally an inflammatory reaction at that point. The features of the reaction which interest us here are (1) the increased blood supply which brings phagocytes and bacteriolytic serum to act on the invading organisms; (2) the fact that there is a proliferation of the local and circulating tissue cells which on the one hand produces phagocytes and which on the other hand builds a wall of cells about the invading organism. The story of inflammatory reaction is longer than there is time to relate here. But these several facts serve to illustrate its protective character.

Acquired immunity.—So far in our discussion we have been concerned mainly with factors in what is called natural immunity. We have been considering the bodily defenses that are always

present in the normal healthy individual. These defenses are frequently overcome by disease, and pathogenic organisms then establish themselves in the tissues of the body, as in pneumonia, tonsillitis, diphtheria, and so on. Under these conditions the body usually acquires a new internal defense which enables it to destroy the invading pathogenic bacteria and expel them. We then say: "The disease has run its course. He is well." Sometimes this acquired defense is so strong that it becomes permanent. We usually do not have smallpox a second time. We call this defense against disease "active acquired immunity."

The mechanism of this process by means of which the animal body is able to organize a new and powerful defense against disease is one of the wonders of physiology. Here we can do no more than point out a very few of the more important facts, but it is well worth while to go deeper into this marvelous story.

When an infecting agent, like a pathogenic bacterium, establishes itself in the tissues, it appears to have an irritating influence upon some or possibly all the fixed and circulating cells of the body. This irritating or stimulating influence may be due to soluble chemical particles arising from the secretions or excretions of the pathogens or from the disintegration of the dead bodies of the invading pathogens. These chemical bodies are carried about by the blood stream and are thus brought into contact with the various tissue cells in all the organs of the body. And then a remarkable thing happens. The irritation of these tissue cells seems to stimulate some, possibly all of them, to produce specific antibodies which destroy the infecting organisms or neutralize the toxic products of their activity.

We call the soluble chemical agents that cause the tissue cells to produce these antibodies "antigens." An antibody which neutralizes a toxin we call an "antitoxin." An antigen which causes the production of a lysin we call a "lysogen." We know a number of well-established groups of antigens and their corresponding antibodies. For our purposes the most important of these are the toxins, the lysogens, and the opsogens, and their antibodies, the antitoxins, the lysins, and the opsonins.

The toxins are soluble poisons usually produced by pathogenic bacteria. The toxins of diphtheria and of lockjaw are poisons of terrible power. Each acts as an antigen and produces an antitoxin.

The lysogens are antigens that cause the tissue cells to pro-

duce lysins. Typhoid bacilli produce lysogens. When they are present in the tissues they cause the appearance of lysins that dissolve and destroy typhoid bacteria. Lysins that destroy bacteria are called bacteriolysins.

The opsogens are of great importance and are, in addition, unique in their mode of action. The opsogens are important because without them the white blood corpuscles do not exercise their powers of phagocytosis.

Summary.—When certain disease organisms establish themselves in the tissues they act as general tissue-cell irritants. Under the influence of this general irritation the cells of the body produce antibodies that destroy the invading organisms or neutralize the poisons which those organisms produce. In this manner the cells of the human body respond to the call "to arms" and defend themselves from destruction through disease.

Source of antigens.—Antigens are soluble protein bodies concerning which much yet remains to be learned. The antigens that interest us are those that are formed by pathogenic organisms.

Extra-cellular antigens.—We know that some antigens are released by such organisms in their excretions and secretions. Antigens given off in this manner may be called extra-cellular antigens. Several of the toxins given off by the diphtheria bacillus are extra-cellular antigens. Toxins of this sort are frequently called ectotoxins or exotoxins.

Intra-cellular antigens.—It seems to be true, too, that many pathogenic organisms contain poisonous substances that are structurally parts of those organisms and are released only when those organisms die and become disintegrated. These intra-cellular poisons then go into solution and may then act as antigens. Such antigens may be called intra-cellular antigens. The existence of antigens from this source has not been proved but there is ample indication that there is such a source.

We may summarize our statements on the sources of antigens by saying that the antigens manufactured in infectious diseases are given off in the secretions or excretions of living pathogens or they are dissolved out of the dead bodies of such organisms.

Sources of antibodies. — Metchnikoff produced voluminous evidence that the antibodies are products of the white blood corpuscles and other phagocytes. Ehrlich supported the view that the connective tissue cells are the chief sources of the antibodies.

It may be that antibodies are manufactured by all active tissue cells under varying circumstances.

Active acquired immunity.—The animal (or man) that is protected by antibodies of its own manufacture is protected by an active acquired immunity—or rather by an immunity which it has acquired actively.

Passive acquired immunity.—On the other hand, when an animal (or man) is protected by antibodies that have been transferred to it from some other animal, in the tissue cells of which those antibodies were manufactured, we say that animal has been protected by an immunity which it acquired passively.

Active acquired immunity is the defense which an individual manufactures within his own tissues to save him from a specific infection. Passive acquired immunity is the defense which an individual may acquire through the injection into his tissues of defenses manufactured by the tissues of some other animal. The factors in immunity acquired actively by one animal may, therefore, be used passively by another animal.

Our surface defenses and certain of our internal defenses operate to prevent our becoming sick. The skin, mucous membranes, the cleansing and antiseptic secretions, the cilia, the phagocytes, the lysins, and other less well-known agents of natural immunity participate in this defense.

The antibodies are the internal defenses which we organize to save us from destruction when our natural surface and internal defenses have proved insufficient to protect us from invasion by pathogenic organisms. Recovery from infectious disease depends upon this acquired immunity. Death comes when the acquired immunity is not strong enough—quantitatively or qualitatively—to overcome the invading pathogenic organisms and their poisons.

This acquired internal defense is remarkable in many respects. (*a*) It is a specific defense. The antibodies manufactured for defense against the poisons of diphtheria will not offer any defense against the poisons produced by the bacillus of typhoid fever or the treponema of syphilis or from any other source. (*b*) This acquired defense may last for a very short time and then disappear, as in diphtheria. It may leave behind it an increased susceptibility to the pathogenic organism against which it was developed, as in influenza or pneumonia. It may leave a sensitiveness which enables the tissue cells to manufacture new antibodies against the

same disease more rapidly than before the first attack, as in cholera. (*c*) It may last a long while, as in smallpox or measles.

Antigens and antibodies in action as found in diphtheria.—Diphtheria is a common disease. More than six hundred persons died of this disease in New York City and there were more than ten thousand cases in that city in 1928. It is caused by the diphtheria bacillus. This pathogen most commonly locates itself in the throat. When the bacillus of diphtheria establishes itself in the human throat, if conditions are favorable, it reproduces very rapidly, so that in a few hours there may be many millions of new bacilli. Each one of these living organisms takes its food from the tissue in which it is located. This tissue is the mucous membrane of the throat. All of its excretions and secretions are deposited in that same tissue. When the organism dies its body disintegrates and its chemical structure dissolves in the fluids in which it has been living. These soluble chemical products of the life and death of the diphtheria bacillus are carried by the blood and lymph circulations to every organ, every tissue, and every tissue cell of the human body.

Several of the soluble chemical products of the life and death of the diphtheria bacillus may be noted as follows:

Toxin of diphtheria.—The toxin of diphtheria is particularly poisonous. One cubic centimeter of a filtered bullion culture (about the contents of a small-sized thimble) contains enough poison to kill two thousand average-sized guinea pigs. Before the days of antitoxin treatment of diphtheria this toxin destroyed from twenty to fifty per cent of all the children infected with the diphtheria bacillus.

Antitoxins of diphtheria.—The toxin of diphtheria acts as an antigen stimulating the tissue cells (the phagocytes—Metchnikoff; the connective tissue cells—Ehrlich) to produce antibodies known as antitoxins. These antibodies (the antitoxins) are factors in active acquired immunity. They are nowadays supplied the individual by the physician and thus offer a passive acquired immunity.

Since the introduction of the antitoxin treatment of diphtheria, death from that disease has been greatly reduced. "Bayoux makes the statement, based upon an analysis of 230,000 cases, that the death-rate of diphtheria before antitoxin was 55 per cent,[1]

[1] Osler's *Modern Medicine,* first edition, II, 340.

and that since the advent of the serum it has fallen to 16 per cent." Since Bayoux's time the quality and methods of using antitoxin have been improved. As a result, the death-rate from diphtheria has been reduced almost to zero when antitoxin is given early.

The earlier the antitoxin is used the more certain is its action. This is shown in the following statistics:

Report of the State Board of Health, Massachusetts, 1902

No. of Cases	Date of Giving Antitoxin	Percentage of Mortality
1433	1st day	7.9
3284	2d day	6.2
2654	3d day	9.0
1684	4th day	12.9
864	5th day	15.9
1242	6th day (and later)	17.6

Lysogens and lysins of diphtheria.—It seems to be well established that there are antigens produced by the diphtheria bacillus that cause the tissue cells to produce specific bacteriolysins. We do not know how important the bacteriolysins of diphtheria are, but we believe that they take a more or less effective part in the defense of the body against the diphtheria bacillus—that is, in recovery from diphtheria.

Opsogens, opsonins, and phagocytes of diphtheria.—The soluble chemical products of the life and death of the diphtheria bacillus contain an antigen that is called an opsogen. This antigen when distributed in the blood stream causes certain of our tissue cells to manufacture a specific opsonin for the diphtheria bacillus. The specific opsonin for the diphtheria bacillus attacks this bacillus in some, at present, unknown way, and causes that organism to become susceptible to the phagocytes (white blood cells), so that these phagocytes will then engulf diphtheria bacilli and destroy them. We are justified in believing that the opsogen of diphtheria is of great importance in its productive relation to the opsonin of diphtheria and, therefore, to the specific phagocytosis of diphtheria. The number of phagocytes (white blood cells) in the blood is greatly increased in the majority of cases in diphtheria. This increase is well marked by the third day of the disease. The number of white cells may then have increased from 3,000 to 4,000 per cubic millimeter to such enormous numbers as 38,000

per cubic millimeter (Billings), or 46,000 (Morse), or 75,000 (Bouchut), or 148,229 (Felsenthal).[1] These phagocytes may each take up from 30 to 50 bacilli.

There is a possibility that there is a production of unknown antigens by the diphtheria bacillus with consequent unknown antibodies produced by the human tissue cells.

There may be other extra-cellular antigens produced by the bacillus of diphtheria which we have as yet been unable to identify. Their antibodies are, of course, not known. There may be intra-cellular antigens of the diphtheria bacillus which are dissolved and released into the blood stream when the dead bacillus is destroyed either by lysins or through phagocytic digestion.

There is the possibility that the human tissues produce "antigens" which cause the diphtheria bacillus to produce "antibodies." The human antibody is produced for defense against certain germs. It seems to be true that the germs may produce antibodies of their own which protect them against the human being.

Aggressins of diphtheria.—It often happens that the bacillus of diphtheria shows an unusual virulence. This may be due to the fact that it is stimulated to produce active defenses against its human host. Those defenses are called aggressins. The indications are that living, virulent microbes excrete or discharge substances which are not toxins proper but which, nevertheless, have an inhibitive or "anti" action upon the cells of the organism. "It may, indeed, be suggested that the aggressins are to the bacterial organism what the opsonins are to the animal" (Adami). And so, while the tissue cell is manufacturing specific defenses against the invading cell, each is producing chemical bodies that are antigens to the other and antibodies for itself.

Toxin-antitoxin for the production of active immunity in diphtheria.—An active immunity that appears to be permanent has been secured by injecting a carefully measured mixture of diphtheria toxin and antitoxin at intervals of one week until three injections have been given. The mixture is such that a little more toxin is used than is neutralized by the antitoxin. Thus each dose contains some free toxin that serves as an antigen and stimulates the tissue cells to produce antitoxins of their own. Thus a slowly increasing active immunity develops during a period of eight or twelve weeks. This treatment establishes a lasting immunity

[1] See R. C. Cabot, *Clinical Examination of the Blood.*

against diphtheria. The method has been successfully used for the protection of tens of thousands of children in New York City. The toxin-antitoxin immunization is not so important for older people because from eighty to ninety-five per cent of adults are immune.

Summary.—(*a*) The bacillus of diphtheria injures and destroys human life with the following antigens: (1) toxins; (2) lysogens; (3) opsogens; (4) aggressins; (5) various unknown, extra-cellular, and intra-cellular products. (*b*) The human body may be defended against the diphtheria bacillus: (1) actively, by specific antitoxins, bacteriolysins, and opsonins, by phagocytes, anti-aggressins, and various other unknown antibodies; (2) passively, by antitoxin manufactured in another animal—usually a horse—and injected into the circulation; (3) by a permanent active immunity produced by the use of toxin-antitoxin injections.

Conclusion.—(*a*) Our natural immunity protects many of us so that we never have diphtheria. It is not strong enough in some persons to protect them and as a result we have more than 225,000 cases a year in the United States. There were 5,418 deaths from this disease reported in 1932.

b) Our powers of active acquired immunity have been able in the past to save from death only from fifty to eighty per cent of all persons infected with the diphtheria bacillus.

c) Our powers of active acquired immunity, assisted by the immunity we have been able to secure from commercial antitoxin (passive acquired immunity), or by commercial toxin-antitoxin (active acquired immunity), have been able to save from death from eighty-four to ninety-three per cent of the human beings who have had the benefit of this combined defense. It is believed that a very early use of diphtheria antitoxin would save life in nearly every case.

Duration of immunity.—The antibodies which we have discussed under diphtheria produce only a transient immunity. Repeated infections with diphtheria bacilli are common. The immunity produced in defense against these organisms lasts for a short time only.

The immunity produced in pneumonia, bronchitis, tonsillitis, and common colds is transient. In some cases one attack of disease seems to predispose the individual to subsequent attacks. This is

especially true of lobar pneumonia, influenza, erysipelas, bronchitis, and malaria.

A more lasting immunity occurs after the following diseases: smallpox, yellow fever, measles, whooping cough, scarlet fever, cerebrospinal meningitis, infantile paralysis, typhoid fever, typhus fever, chicken-pox, and mumps. In these infections the tissue cells produce antibodies which may remain in the blood and tissue juices for longer periods of time. It is more probable that in these cases the cells continue producing specific antibodies for months or years after recovery. We have not yet learned the details of the campaign of offense and defense in these various infections. We feel safe in deciding that it is a campaign in which antigens and antibodies participate in the various characteristic ways already pointed out in these pages. We have, therefore, a general understanding of these methods of warfare, though we do not know all the details of any specific campaign.

The use of antibodies for the protection of the community.—Our knowledge of immunity has shown us various ways in which we can aid the individual to recover from certain diseases and with which we can protect the individual and the community from certain epidemics. The use of passive acquired immunity for the reduction of mortality from diphtheria has been discussed above.

Immunity against smallpox.—The immunity produced by vaccination against smallpox is an active immunity developed by a mild disease, cowpox, which is also an immunity against the very much more serious disease, smallpox. Such vaccination causes vaccinia (or cowpox) in the human. The human being who has had vaccinia is absolutely protected thereby against smallpox for a period of from two to seven years. The experience of over one hundred years offers convincing proof of the pronounced difference in the mortality and morbidity from smallpox in the vaccinated and the unvaccinated. The table on page 431, from Schamberg, shows that, among thousands of cases of smallpox occurring in cities all over the world, the death-rate from smallpox has been from five to sixteen times greater among the unvaccinated than among the vaccinated.

The United States authorities vaccinated 3,515,000 persons in the Philippine Islands during the few years of their early control without a single death from the vaccination itself. The discomfort

and injury that sometimes follow vaccination are usually if not always due to carelessness in performing the vaccination or in the treatment of the vaccination sore. If such sores are treated aseptically—as all wounds should be treated—they remain innocent and harmless.

TABLE I

Death-Rate from Smallpox among Vaccinated and Unvaccinated in Various Countries*

Place and Time of Observation	Total Number of Cases Observed	Death-Rate per 100 Cases	
		Among the Unvaccinated	Among the Vaccinated
France, 1816–1841	16,397	16.125	1.
Quebec, 1819–1820	2	27.	1.66
Philadelphia, 1825	140	60.	0.00
Canton Vaud, 1825–1829	5,838	24.	2.16
Verona, 1828–1829	909	46.66	5.66
Milan, 1830–1851	10,240	38.33	7.66
Breslau, 1831–1833	220	53.8	2.11
Wurttemberg, 1831–1835	1,442	27.33	7.1
Carniola, 1834–1835	442	16.25	4.4
Vienna Hospital, 1834	360	51.25	12.5
Carinthia, 1834–1835	1,626	14.5	0.5
Adriatic, 1835	1,002	15.2	2.8
Lower Austria, 1835	2,287	25.8	11.5
Bohemia, 1835–1855	15,640	29.8	5.16
Galicia, 1836	1,059	23.5	5.14
Dalmatia, 1836	723	19.66	8.25
London Smallpox Hospital, 1836–1866	9,000	35.	7.
Vienna Hospital, 1837–1856	6,213	30.	5.
Kiel, 1852–1853	218	32.	6.
Wurttemberg (no date)	6,258	38.9	3.5
Malta (no date)	7,570	21.07	4.2
Epidemiological Society Returns (no date)	4,624	23.	2.9

* Extract from papers prepared in 1857 by Sir John Simon, medical officer of the General Board of Health of England, and at that time laid before Parliament with reference to the History and Practice of Vaccination. Published in first *Report of the Royal Commission on Vaccination, 1889,* Appendix I, p. 74. (From *Preventive Medicine and Hygiene,* by Rosenau, p. 29.)

Smallpox vaccination in the Philippines.[1]—During the Spanish control of the Philippines and for several years after the American occupation, the annual death-rate from smallpox in the

[1] Taken from Heiser and Leach, *Journal of the American Medical Association,* July 1, 1922.

Islands was over forty thousand. After systematic vaccination was introduced the death-rate dropped to zero in those provinces in which such vaccinations were enforced. There was not a single death from smallpox in Manila for the seven years prior to 1914. The only deaths from smallpox in the Philippine Islands during that period occurred in the remote places in which there were no means for preserving the vaccine against the damaging effects of tropical heat, which in the Philippines rarely drops under 90 degrees Fahrenheit. At that time we had not learned how to make vaccine that would not deteriorate if stored outside a refrigerator. Parts of the Philippines have no ice.

After 1914 general vaccination was not effectively carried out. Minor health officers and vaccinators reported vaccinations as having been made that were not made. Vaccine was allowed to deteriorate for lack of care. Quantities of vaccine were thrown away. Much of it was found in wastebaskets by investigators. More vaccinations were reported for some districts than would have been possible with all the vaccine then available. In one district the total number of vaccinations reported exceeded the total population by fifty thousand.

As a result of these failures to secure vaccinations there grew up a huge unvaccinated population in the Philippines that offered a fertile field for infection. In 1918 the epidemic came. There were fifty thousand deaths in payment for this carelessness and neglect. Ninety-three per cent of the deaths were unvaccinated persons. Eighty-nine per cent of the deaths were unvaccinated children, most of whom were five years old or less.

Before the end of 1918, vaccination was resumed with new preparations that do not deteriorate in tropical heat. Smallpox has again disappeared in those Philippine districts in which systematic vaccination has again been enforced.

According to the records of the United States Public Health Service for the year 1928, the Philippine Islands are better protected by vaccination against smallpox than are various of the states of the continental United States. This report indicates that there were 5 cases and no deaths reported in the Philippines; 342 cases and 3 deaths in Alabama; 342 cases and 2 deaths in California; 3,427 cases and 13 deaths in Indiana; 1,236 cases and 4 deaths in Ohio; and a total of 38,432 cases reported from 47 states and 139 deaths for 46 of those 47 states.

Immunity against rabies.—The Pasteur treatment of rabies develops an active immunity in the individual by repeated short interval infections with attenuated (weakened) organisms of rabies. Of 54,620 persons treated early at twenty-four Pasteur Institutes, less than eight per cent died of hydrophobia. In Hungary, between 1880 and 1885, 5,899 persons were bitten and 4,914 received the Pasteur treatment. Two per cent died among those treated. About fourteen per cent of all persons bitten by rabid dogs and who are not given the Pasteur treatment die of hydrophobia. There were twelve deaths from rabies in the United States in 1932.

Immunity against typhoid.—Immunity against typhoid fever lasting from three to five years is produced by the injection into the tissues of emulsions of dead typhoid bacilli. Vaccination against typhoid fever is now practiced in various armies, numerous hospitals, and by many wise individuals. The results have been universally satisfactory. In continental United States, in 1908, one person in every two hundred had typhoid fever. In our Spanish-American War, out of 107,000 troops, 20,000 had typhoid fever. In 1911 anti-typhoid vaccination was given 12,801 soldiers at San Antonio, Texas. Only two cases developed. One had not been vaccinated and the other had been infected before vaccination. In the small city of San Antonio at that same time there were 49 cases of typhoid fever with 19 deaths. The incidence of typhoid fever in the British Army in India is 1.7 per 1,000 among the vaccinated and 5.3 among the nonprotected. (Before the World War.) If the American Expeditionary Force (2,000,000 men) had not been vaccinated against typhoid fever and if the same rate of infection with typhoid had occurred as did occur in our Spanish-American War there would have been 384,113 cases and 29,266 deaths from typhoid in our American Expeditionary Force; as a result of preventive immunization there were less than 3,000 cases with 213 deaths.

This protective treatment of typhoid fever has apparently very little danger attached. Sometimes fever and discomfort follow such "vaccination," but when they are the results of the vaccination they are never serious.

Protective methods of treatment like these have been or are being devised for pneumonia, tetanus, cholera, bubonic plague, and other diseases.

It is obvious that the products of immunity reactions are of the greatest value in the protection of individual and public health. Immunity is more than a defense which the individual manufactures unconsciously for his own protection. It is now a protection which may be intelligently guided, directed, and reinforced for personal and community benefit.

The market is full of serums for the prevention and treatment of disease. It is always unwise to try new medication until its value has been established by scientific medical authority, and never unless prescribed by a competent physician.

CHAPTER XXXIV

MAN AS A CARRIER OF PATHOGENS

Dissemination of pathogenic organisms by way of human excretions and discharges.—When we remember that only a few pathogenic organisms reproduce in nature, and that all forms under favorable conditions will live and reproduce in the human body, we are forced to the conclusion that man himself is the most important and the most dangerous carrier of pathogens.

Man is a carrier of disease because of the pathogenic organisms which he distributes about him by way of his various excretions in health, in disease, and during recovery from disease. The relation of these various excretions to the spread of disease may be outlined as follows:

From the nose and throat: (*a*) *In health.*—The following organisms may be discharged: pus cocci, the organisms that cause boils and abscesses; streptococci, the organisms that cause severe inflammation with general toxemia (poisoning); pneumococci, the organisms that cause one form of pneumonia, as well as some other diseases; and diphtheria bacilli. During a certain epidemic in Middletown, Connecticut, over two per cent of the throats of 4,081 apparently healthy individuals showed diphtheria bacilli. After the epidemic subsided, over one per cent of these individuals showed diphtheria bacilli. The cocci of meningitis have been found in the noses and throats of apparently normal persons. The cause of infantile paralysis has been found in apparently normal throats. It is possible that the specific causes of the following diseases may be present in the upper air passages of healthy persons: scarlet fever, measles, whooping cough, and mumps.

b) *In disease of the upper air passages and lungs.*—The organisms that cause colds in the nose, throat, and lungs; influenza; bronchitis; the various sorts of pneumonia; syphilis; diphtheria; infantile paralysis; tuberculosis; bubonic plague; measles; trench mouth; Vincent's angina; and scarlet fever are present abundantly during the time in which they are causing active disease in the upper air passages.

c) *During recovery from disease* of the respiratory tract, and sometimes for indefinitely long periods afterward, the various or-

ganisms noted under (*b*) are eliminated in the secretions and discharges from the respiratory tract. Note the importance of this fact in relation to the distribution of these pathogens. The carrier and disseminator is perfectly well and gives no evidence of his danger to others.

Methods of elimination.—These organisms are carried out of the body in health and disease by sneezing, coughing, spitting, blowing the nose, forceful talking, forceful whispering, forceful breathing, and by swallowing.

Methods of transmission.—The pathogens contained in these discharges from the nose and mouth in health and in disease may reach other people in the following ways: (1) *By direct transmission* of organisms from one person to another, as in (*a*) contact infection from kissing, dirty fingers or other parts that have been smeared with these discharges, the use of a common spoon, eating another person's apple core, chewing the baby's food before giving it to the baby, using the same spoon to feed yourself and the baby at the same time; or (*b*) droplet infection from coughing, sneezing, and other forms of forceful breathing. (2) *By indirect transmission* by way of contaminated dust, food and drink, articles in common use, and vermin (such as rats, mice, flies, water-bugs, fleas, bedbugs, and lice). The common bucket, dipper, sponge, or towel used for the accommodation of football or basketball teams during a game are more nearly direct than indirect methods of transferring organisms of disease.

Conditions favorable to the transmission of pathogens from one person to another by way of the excretion and discharges from the nose and mouth are found (*a*) in crowded living quarters; (*b*) in crowded transportation facilities; (*c*) in crowded locker rooms and training quarters; (*d*) in army camps, trenches, transports, etc.; (*e*) among groups of people gathered for any purpose; and (*f*) wherever careless people are found.

The importance of the human being as a carrier of disease through the dissemination of his nasal and oral excretions and discharges is made evident by the following facts: (*a*) This is practically the only way in which these diseases are spread from one person to another. (*b*) These diseases represent an enormous amount of human misery, suffering, and loss of life.

From the ears and eyes.—There are no pathogenic organisms discharged in this manner *in health.* The middle ear and the

eye drain by their respective canals into the nose, so in disease the ear may be affected by various pus organisms and by any of the organisms that cause disease of the nose and throat.

In disease the important pathogenic organisms that are found in the discharges from the eyes are the cause of pink eye and the cause of trachoma; the gonococcus in case of gonorrheal ophthalmia; and any of the organisms that cause diseases of the eye or nose. Discharges from the ears and eyes may transmit the causes of such diseases as scarlet fever, measles, diphtheria, or mumps, when those diseases are present.

These infections may be transferred by towels, handkerchiefs, or fingers.

From the intestinal tract.—The pathogenic organisms eliminated in this manner are:

In health (apparent or real).—The colon bacillus is the most common inhabitant of the lower intestine. It is not normally an actively pathogenic organism. It not infrequently becomes virulent. It is always present in the intestinal canal. The bacillus of typhoid fever has been found in the feces of apparently healthy individuals who have no history of typhoid. One investigator has isolated forty-four varieties of bacteria from forty-eight specimens of feces. Most of these forms are non-pathogenic, but they include the bacillus pyocyaneus, bacillus aerogenes capsulatus, bacillus of tuberculosis, bacillus subtilis, as well as other forms that are known to be pathogenic. The amoeba is sometimes present. The hookworm frequently is present without symptoms. A number of less common higher-animal parasites have been found in the feces of human beings who are apparently well.

In disease.—The organism that is causing an intestinal disease is usually present in large numbers during the period of the infection. Under such circumstance the bacillus of typhoid fever is present, or the spirillum of cholera, or the bacillus of dysentery. The animal parasites that cause intestinal disease and are therefore present during such disease are amoeba, tapeworm, hookworm, and a great variety of other worms.

In recovery from disease, and for a greater or lesser time afterward: Some of the organisms that cause intestinal disease, possibly many of them, remain as inhabitants of the intestinal canal for varying periods of time after the individual has recovered. The bacillus of typhoid has flourished in the gall bladder and

been found in the fecal discharges fifty-five years after recovery of the patient.

Methods of elimination: In the feces. — One-third of the weight of the dried feces passed by the normal individual is made up of bacteria bodies. The average normal daily output by way of the bowels is estimated at 128,000,000,000 bacteria. Ninety-nine per cent of the bacteria in normal feces are dead, but the remaining one per cent may amount to many hundred millions of live bacteria. In disease the output of bacteria in the feces is enormously increased. The tapeworms, hookworms, and other animal parasites reproduce in the intestinal canal, and their eggs or offspring are then discharged in the feces.

Methods of transmission.—The pathogenic organisms contained in the feces are conveyed to other people as follows: directly through contact with soiled hands or other parts of the individual; indirectly through infection of food, water, articles in common use, and infection of food animals, household pets, vermin.

Conditions favorable to the transmission of disease from one human being to another by way of the feces: (*a*) failure to wash the hands or insufficient hand washing after using the toilet; (*b*) yard privies and open sewers accessible to flies and other insects and vermin; (*c*) bad sanitation of food animals; (*d*) warm, moist weather; (*e*) bad domestic and community sanitation. Note the ease of transmission in trench warfare and careless camp life.

Importance of the human being as a disseminator of disease through his fecal discharges: If man would so handle the excretions from his bowels that they would not get into the food and drink of animals or other men, there would soon be no more typhoid fever, no more cholera, and no more tapeworm. If he took care of his dejections properly, hookworm would disappear. There were 350,000 people sick with typhoid fever in the United States in 1914. This means that human feces (or urine) had polluted the food or drink of 350,000 human beings. Thirty-five thousand died. There are some hundreds of millions of men, women, and children in this world sick with hookworm. And every case has come from contact directly or indirectly with human feces.

From the genito-urinary tract.—The pathogens that most commonly cause diseases that at least begin in the genito-urinary tract are the gonococcus and the treponema pallidum. The gonococcus causes gonorrhea and the treponema causes syphilis.

During the active stages of their diseases these organisms are abundantly present in the discharges from the genito-urinary canals.

After apparent recovery they are likely still to be present. The gonococcus usually establishes itself in one or more of the various organs of the genital tract and is discharged in small numbers from time to time in urination, menstruation, or during sexual intercourse. The man or woman with gonorrhea is usually a carrier of the gonococcus for months if under careful treatment, and permanently if the treatment is not faithfully carried out. The treponema of syphilis is likewise an inhabitant of the genital tract for months or even years after infection. But syphilis may be cured if persistent treatment is followed for two and a half or three years.

The organisms that cause infections of the genito-urinary tract escape by way of the urinary and genital discharges.

They are transmitted from one person to another mainly by contact through sexual intercourse. These pathogens may be distributed by soiled fingers. Indirect transmission may be accomplished by the contamination of articles in common use. The treponema of syphilis is present in the mucous patches that appear in the mouth so that kissing may be a method of direct transmission. Or the organism may be distributed in any of the various ways in which the pathogens of the upper air passages are disseminated. These possibilities are described above. It is impossible to fully appreciate or adequately state the importance of these venereal or so-called social diseases. They are pandemic. No country in the world is free from them. This has been true ever since the pandemic of the fifteenth century when syphilis broke out in all parts of Europe. In every great city investigators tell us that many men and boys visit prostitutes every day. Every man and every boy that makes this his practice will sooner or later have syphilis, or gonorrhea, or both. There must be thousands of persons suffering with these diseases in New York City, Chicago, Philadelphia, Los Angeles, San Francisco, and every other large city of the civilized world. It has been shown in some armies in active warfare that more men have been incapacitated by venereal disease than by their human enemies. The fighting strength of an army may be reduced twenty per cent by venereal disease.[1] The importance of

[1] Statement of the American Social Hygiene Association, summer of 1917.

gonorrhea and syphilis arises from the following facts: (1) These diseases are universal. (2) They are associated with sin, shame, and crime. (3) They ruin the family and the home. (4) They are passed on from the guilty to the innocent. (5) Gonorrhea makes men sterile, unable to become fathers; women sterile, unable to become mothers. (6) Syphilis destroys more young and unborn infants than any other cause. (7) Gonorrhea makes more children blind than any other cause. (8) Syphilis places more men, women, and children in asylums for the insane and feebleminded than any other cause. (9) Syphilis cripples the brain, the nerves, and the muscles. Gonorrhea cripples the joints. Both these diseases deform and incapacitate men, women, and children, mentally, morally, and physically. (10) They destroy individuals, ruin homes, demoralize communities, and defeat armies.

Don't forget: These diseases are caused by living organisms which grow only in human beings. These organisms are distributed from one human being to another most commonly through contact with genito-urinary excretions. The only common carriers of these diseases are the prostitute and the man of loose morals.

By way of the skin.—The skin may mechanically carry certain organisms which live on it or in it. The most important of these organisms are pus cocci; streptococci; pathogenic contaminations from discharges from the eyes, ears, nose, mouth, rectum, genito-urinary tract, and infected wounds of the skin; the fungus of "foot itch" (epidermophytosis); and various parasitic insects.

Certain pathogens have been found in sweat, e.g., the typhoid bacillus and the tubercle bacillus. This occurrence is not common.

Certain organisms that live in the blood may be drawn through the skin by blood-sucking insects. Some of these organisms and the insects that carry them may be enumerated as follows: (*a*) The plasmodium of malaria. It may be present without symptoms. The plasmodium is carried by the anopheles mosquito. (*b*) The cause of dengue is carried by a mosquito. (*c*) The cause of yellow fever is carried by a mosquito. (*d*) The filaria are carried by mosquitoes. There are several diseases caused by filaria. Most of them are unimportant. (*e*) The trypanosome of sleeping sickness is carried by a biting fly. (*f*) The cause of typhus fever and the cause of trench fever are carried by the louse. (*g*) The bacillus of bubonic plague is carried by a flea. (*h*) The cause of Rocky Mountain or spotted fever is carried by a tick.

Opportunities for blood-sucking insects to draw pathogens from the blood: (*a*) The organisms may be present in the blood in health. Cases are recorded in which malaria parasites have been present with no symptoms. Filaria usually infect with no apparent injury or discomfort to their victims. (*b*) Organisms present in the blood in disease. In addition to the pathogenic organisms noted above which locate themselves in the blood and thus cause disease, there are periods during infection from many other organisms during which those organisms are present in the blood. Typhoid bacilli, tubercle bacilli, treponema of syphilis, gonococci, streptococci, and other organisms have been demonstrated in the blood of patients. (*c*) Organisms that persist in the blood after recovery of the patient are few in number. The malaria parasite may persist occasionally.

Methods of elimination.—The insects puncture the skin and suck blood containing pathogenic organisms. These organisms may simply remain alive in the puncturing apparatus or stomach of the blood-sucking insect or they may pass through a cycle of development in the insect.

Methods of dissemination.—The insect carrier either mechanically contaminates the food of human beings, or injects the pathogenic organisms it carries into the blood of the next person it bites, or it deposits pathogens on the surface of the skin.

Conditions favorable to transmission by insects.—Congestion and poor personal hygiene favor bedbugs, lice, and fleas. Bad community sanitation favors mosquitoes and flies. Poverty and ignorance favor vermin. Army life during periods of active service is favorable to such vermin as body lice. Typhus fever, carried by body lice, is one of the important diseases of armies. The World War reported epidemics in Turkey, Servia, Russia, and other countries. Trench fever, carried by a louse, is a product of the World War.

Importance of human beings as disseminators of disease by way of the skin: It was estimated in 1912 that there were 1,500,000 cases of malaria a year in the United States, with 12,000 deaths. There were 2,568 deaths reported from the area of registration inclusive of Hawaii in 1932.

In 1878 there were 15,000 deaths from yellow fever in 132 United States towns. The epidemic represented the loss of $100,000,000. There have been no epidemics here in recent years.

Sleeping sickness has devastated whole sections of Africa, destroying the natives by the thousand. Typhus fever at one time was the scourge of every army. Bubonic plague is a common epidemic in the Orient, and is accompanied by an enormous mortality.

Summary.—(1) Man is a carrier of disease because of the pathogenic organisms which he distributes about him in health and disease and after recovery from disease by way of his (*a*) respiratory tract, including his nose, throat, and mouth; (*b*) eyes and ears; (*c*) intestinal tract; (*d*) genito-urinary tract; and (*e*) skin.

2. These organisms may be transferred from one person to another by (*a*) direct contact ("contact infection"); (*b*) secondary carriers, such as infected sewage, food, water, air (droplet infection, dust infection), dust, dirt, and soil; articles and materials in common use (that is, by more than one person at a time); insects and animals.

3. When we remember that only a few forms of pathogenic organisms reproduce in nature and that all forms under favorable conditions multiply freely in the human tissues, we are forced to the conclusion that man himself is the most important and the most dangerous carrier of pathogens. In the great epidemics of history he has been the agent that has disseminated such diseases as cholera, typhoid fever, smallpox, yellow fever, syphilis, bubonic plague, and typhus among the nations of the earth.

CHAPTER XXXV

INSECTS AS CARRIERS OF PATHOGENIC ORGANISMS

The insects that are known to carry the organisms that cause disease are flies, mosquitoes, fleas, ticks, lice, bedbugs, water-bugs (?), cockroaches (?), and kitchen ants (?).

In view of the fact that our knowledge of these carriers is only a few years old, we must admit that there may be other insect carriers of whose relation to disease we are not at present aware.

Sources from which insects secure pathogenic organisms.—(*a*) In general, it may be said that these sources are the infected breeding-places and the infected feeding-places of insects. The significant fact in this connection is that human beings and animals are the final sources from which the pathogenic organisms come. These human and animal sources which serve as feeding-places and breeding-places for the insects that may carry the disease are the dead bodies of diseased human beings and animals (uncommon); excretions from men and animals; excretions from persons and animals while sick; excretions from such sources during recovery; excretions from such sources persisting for long periods of time after recovery, e.g., diphtheria, cholera, typhoid fever; excretions from human beings and animals that have not been sick, e.g., diphtheria, other possibilities. The most important sources are the living human beings and animals on which biting and blood-sucking insects feed while their blood contains pathogenic organisms, while the human or animal is sick, during recovery, for long periods after recovery, and, in some cases, with no evidence of any infection at any time.

b) In particular it may be said that the organisms that cause disease may be picked up by insect carriers in the following common breeding-places and feeding-places of those insects: garbage which may contain infectious human or animal discharges; the outlets of sewers where human excretions are found; deposits of manure, droppings from cattle, horses, swine, sheep, chickens, dogs, human beings, and other animals; offal from slaughter-houses, meat markets, and food stores; warm, dark, damp, and dirty places in which human excretions may have been left by human carriers; the bodies of men and animals that have died of infectious disease.

Ways in which insects carry pathogenic organisms: (*a*) *Passively.*—The insect that is a passive carrier of disease may carry pathogenic organisms on the outer surface of its body, as in the case of the house-fly that smears its body with the excretions from a case of typhoid fever or pulmonary tuberculosis on which it feeds. It may carry pathogenic organisms in its intestinal canal. The organisms then may pass through and escape with the excretions, as in the case of the fly that feeds on the intestinal excretions of a typhoid patient or the sputum of a case of pulmonary tuberculosis.

b) *Actively or biologically.*—The insect that is an active carrier of disease becomes for a time necessary to the life of the pathogenic organism. We say then that the pathogenic organism is a parasite and the insect is its host. An example of such an active carrier is the anopheles mosquito, which may carry the pathogenic protozoan that causes malaria.

The distribution of pathogenic organisms by insect carriers.—The insect carriers distribute the organisms of disease in the following ways: (*a*) By wiping or shaking them off their bodies while in contact with the food or drink of human beings, or while in contact with articles in common use, or while in contact with human beings themselves. (*b*) By excreting them with their intestinal discharges. The mosquito usually defecates when it stings. The organism that causes trench fever is contained in the defecations of the body louse. Various pathogenic organisms have been found in the intestinal canal of the mosquito. Tubercle bacilli have been found in the feces of flies. (*c*) By squirting them into the blood of their victims when they sting them, e.g., the anopheles mosquito and the tsetse fly. (*d*) And possibly, through their remains which may be smeared on the skin when the biting insect is crushed by a blow from the resentful victim.

Insects known to be active or biological carriers of disease: *The wood tick* (*Dermacentor andersoni* Stiles).—A tick found in the Rocky Mountains and elsewhere is a biological carrier of Rocky Mountain tick fever and of the bacterium that causes tularemia. The mortality of Rocky Mountain tick fever is between seventy and eighty per cent; of tularemia, three per cent or more.

Ornithodros moubata carries "African tick fever," which is one of the scourges of Africa.

The biting flies.—The tsetse fly carries the trypanosome of sleeping sickness. This trypanosome was discovered by Bruce and Castellani in 1902. Sleeping sickness is an absolutely fatal disease that has destroyed hundreds of thousands of human beings in Africa.

Certain mosquitoes.—*Culex fatigans* carries dengue or break-bone fever. In 1895, 50,000 out of a population of 65,000 had the disease in Charleston, South Carolina. The pain is excruciating. There is no mortality in the otherwise strong. The parasite is not certainly known. There is some evidence that it goes through a cycle in man and another in the mosquito.

Anopheles, culex, panoplites, and other mosquitoes carry *Filaria Bancrofti.*[1] Thirty to forty per cent of the South Sea Islanders have filaria in their blood; ten to fifty per cent in China. This disease, as a rule, causes no symptoms. It occurs in tropical and sub-tropical countries. The adult worm lives in human tissue (the lymphatics). It looks like a thread from three to four inches long. The embryos or larvae swim free in the blood and are thus sucked up by the mosquito. The embryo or larva undergoes a cycle of changes in the tissues of the mosquito lasting fourteen days or longer, depending on the temperature.

The mosquito *Stegomyia calopis*[2] carries the cause of yellow fever. The United States has lost more lives in the past from this disease than any other country. We have noted above that in 1878 an epidemic affected 132 towns in our Southern states with 15,000 deaths and a loss of over $100,000,000. Texas, 1903, had over 1,000 cases. New Orleans, 1905, had over 8,000 cases with 900 deaths. Since 1793 the United States has lost over 100,000 lives through yellow fever. There have been no cases in this country in recent years. It has been a serious disease in army camps. There is probably a cycle in man and a cycle of some sort in the mosquito.

In 1897 Ross proved the anopheles mosquito to be the carrier of malarial parasite. There were about 1,500,000 cases a year in the United States with 12,000 deaths, estimated by L. O. Howard in 1912. The morbidity and mortality from malaria has been much reduced in recent years. Ross estimated 1,130,000 fatal cases annually in India. This is another very important disease in mili-

[1] Manson, China, 1876.

[2] Reed, Carroll, Agramonte, and Lazear in Cuba, in 1901, proved the relationship of this mosquito to yellow fever.

tary camps. It goes through a cycle of development in man, and a cycle in the mosquito.

Certain fleas.—The rat flea, *Lemopsylla cheopis,* carries the bacillus of bubonic plague. In the sixth century, one-half of the people of the Roman Empire died from the plague. In the fourteenth century 25,000,000 people died of this disease in Europe. It was called "The Black Death." In the seventeenth century, 70,000 died in London alone. The Oriental pandemic, 1895–1910, left a record of 7,500,000 deaths in India for that period.[1] Bubonic plague is a disease of historical importance in military campaigns. It is caused by the bacillus pestis. The bacillus is transferred from rat to rat and from rat to man by the rat flea which feeds on rats and on human beings.

Insects that may be passive carriers of disease.—*Cockroaches* have been known to carry the bacillus of typhoid fever. The intestinal parasites of certain cockroaches are known to cause malignant growth in rats when eaten by them.

Water-bugs have not been proved to be carriers of pathogens, but their habits are bad and their opportunities are sufficient.

House-ants are in a class with cockroaches.

Body lice are carriers of the cause of typhus fever. The death rate from typhus is from forty to fifty per cent. Lice may carry relapsing fever which has a death-rate of about four per cent. Lice are carriers also of trench fever. Rabbit lice are often carriers of the bacterium tularense.

Bedbugs are known to have carried the spirillum of relapsing fever, the bacillus of bubonic plague, and the bacterium tularense. The bacillus of tuberculosis has been found in the intestinal canal of this insect. Probably not commonly a carrier of any of these pathogens.

The gnat carries the unknown cause of "Adriatic" or "three-day fever." Death rare.

Fleas are chiefly notorious as active carriers of bubonic plague (see above).

Mosquitoes are chiefly notorious as active carriers. They have been found with living tubercle bacilli in their intestines; also the bacillus of leprosy. It is possible that they may carry the bacterium of tularemia.

[1] Martin, *British Medical Journal,* November, 1911.

The house-fly.—In July a single fly has been found to carry on his body as few as 570 and as many as 4,400,000 bacteria; and in his body (intestines) as few as 16,000 and as many as 28,-000,000 bacteria.

The following common pathogenic bacteria have been found on the house-fly or in his intestines or in his feces: bacillus of typhoid fever, spirillum of cholera, bacillus of bubonic plague, the cause of summer diarrhea, and the bacillus of tuberculosis.

The importance of the filthy habits of the house-fly is obvious in relation to the health of the home, the community, and specially in camp and trench life. One of the lessons learned through our disgraceful experience in the Spanish-American War taught us that the fly as a carrier of typhoid fever may be more dangerous to a dirty, careless camp than a human fighting enemy.

Prevention of disease from insect carriers.—Keep pathogens away from insects. Dispose of human and animal excretions and discharges so they may not supply pathogens to insects that might serve as mechanical carriers. The problems of sewage disposal on the farm, in the village, or in the city, or in military camps are problems that have to do with life and death in the community. Sewage discharges into rivers or large bodies of water may endanger the communities that use them. Yard privies are a menace to community health because of their accessibility to flies and other vermin. Keep human carriers away from insects that may serve as active carriers. People with chronic or unsuspected malaria are sources from which the anopheles mosquito secures the pathogens of malaria in the spring. The human with malaria serves as a reservoir through the preceding winter. If all winter cases were treated with anti-malarial measures there would be no reappearance of malaria from such sources. People sick with malaria, yellow fever, and other diseases carried by insects should be kept away from such insects. If the insect—mosquito, biting fly, flea, louse, etc.—has no opportunity to find a human carrier, it will not become a carrier unless there is some other animal that serves as a reservoir from which the insect may secure the pathogen. England had no malaria prior to the World War, but England had many anopheles mosquitoes that would carry malaria if there had been any humans with the disease in England. Following the war, the soldiers returning from malarial countries reintroduced the malarial parasite into England. However, vigorous public health

measures have prevented the re-establishment of malaria in England.

Keep animal carriers away from insects that might secure pathogens from them. It is important to destroy infected rats, ground squirrels, and other animals from which the flea secures the bacillus of bubonic plague. The jungle animals of Africa are sources from which the tsetse fly secures the trypanosome of sleeping sickness. If all such infected animals could be destroyed, there would be no more sleeping sickness.

Destroy the insects that may become carriers. Kill the adult insects. Use fly-traps and fly poisons. Bat towers have been built in Texas for the housing of bats that feed on mosquitoes.

Destroy the breeding-places of insects. Dispose of human and animal excretions so they may not serve as breeding-places for insects. This is an important consideration in building cesspools, privies, latrines, sewers, barns, cow-yards, pig-pens, etc. Dispose of garbage, carcasses of animals, and decaying organic matter so that flies may not breed therein. Drain swamp land, dry up pools and other standing water, so mosquitoes will not breed there.

Use screens on windows and doors. "A yard of screen on the window is better than a yard of crêpe on the door."

CHAPTER XXXVI

ANIMALS AS CARRIERS OF PATHOGENIC ORGANISMS

The animals that are known to have carried disease to man are the dog, cat, cow, horse, sheep, hog, goat, rat, rabbit, parrot, parrakeet, and certain fish. We must admit the possibility of other animal carriers whose relation to disease is yet unknown.

The organisms which animals may carry are pathogenic bacteria, and protozoa, filtrate viruses, and higher animal parasites.

The sources from which animal carriers may secure the pathogenic organisms which they carry are: (*a*) Other animals and human beings (1) by contact; (2) from bites of animals; (3) from excretions through direct contact and through contamination of food, water, droplets of saliva in the air (from sneezing, coughing, etc.), dust, and articles with which the animal comes in contact; (4) carnivorous animals may become diseased through the diseased flesh which they may eat. (*b*) Insect carriers that infect them. Remember that these insects in turn have secured their burdens of pathogenic organisms from other animals or men. They may be passive carriers. They may be active carriers.

Ways in which animals may carry pathogenic organisms: (*a*) As passive carriers; pathogenic organisms may be merely mechanically adherent to the surface of the skin or in the hair, or these organisms may be present in the alimentary tract, living on its surface or in the food therein contained. (*b*) As active carriers. (1) The animal may be sick with some specific disease. It may be a carrier during the active phase of the disease. It may be a carrier while recovering. It may be a carrier for a long while after recovery. (2) It may have organisms of disease living in its tissues or on its external or internal surfaces with no evidence of resulting disease.

Ways in which animals may distribute the pathogenic organisms which they carry: (*a*) Through contact, as in bodily contact with hair, skin, or other parts of the animal which carries disease organisms, or through biting. (*b*) Through excretions that may be released by way of the respiratory tract, the digestive tract, the genito-urinary tract, or open sores or infected wounds of the skin, eyes, or ears. The excretions may infect such secondary carriers as droplets in the air, dust, food, and water of men and animals,

and articles in common use. (*c*) By way of their secretions, such as milk. (*d*) By way of blood-sucking insects that feed on them. (*e*) By way of their diseased dead bodies. (1) Insects and vermin may feed on them. (2) Animals may become infected by feeding on their dead bodies. (3) Diseased carcasses may be sold for food. Food animals may be diseased and their diseased food products put on the market. The United States Department of Agriculture, through its Bureau of Animal Industry, between 1906 and 1912, condemned over 90,000 diseased carcasses and over 4,250,000 parts of carcasses.

Specific carriers.—*The dog* is known to carry skin diseases, respiratory diseases, intestinal diseases, hydrophobia, and diphtheria (puppies). The importance of the dog as a source of injury and as a carrier of rabies is shown in the weekly bulletin of the Department of Health of New York City, February 27, 1918, which reads in part as follows:

Number of Dog Bites Reported and the Character of the Control of the Animals

	1915	1916	Decrease
Total dog bites reported	3,650	3,247	403
Dogs biting while leashed	404	358	82
Dogs biting while muzzled*	404	263	141
Dogs biting while leashed and muzzled	263	120	143
Not leashed or muzzled	2,334	2,333	1
Condition of control not known	209	163	46
Dogs biting (animals licensed)	...	1,254	..
Dogs biting (animals ownerless)	...	247	..
Vicious dogs destroyed (Sec. 10 S. C.)	...	796	..
Rabid dogs (laboratory confirmation)	113	24	89

* Many dogs are only apparently muzzled. Recently the courts have decided that an animal which can still bite is not muzzled within the meaning of the law.

Number of Dog Bites Reported and the Occurrences of Human and Animal Rabies—1907 to 1918, Inclusive

	1907	1908	1909	1910	1911	1912
Total bites	1,104	4,622	5,168	3,792	4,509	4,192
Cases of rabies (human)	28	16	7	7	11	6
Cases of rabies (animals, dogs)	37	104	57	75	212	239
Deaths from rabies (human)	28	16	7	7	11	5

	1913	1914	1915	1916	1917	1918
Total bites	4,366	4,462	3,640	3,247	2,873	2,807
Cases of rabies (human)	8	8	1	1	1	0
Cases of rabies (animals, dogs)	139	318	113	34	31	19
Deaths from rabies (human)	8	8	1	1	0	0

There were nearly 800 cases of rabies in animals reported in California in 1928 and also in 1929. Between 1920 and 1929 in California 5,228 cases of animal rabies were reported, with 41 deaths of human victims of hydrophobia. In 1932 there were 12 deaths in the United States from rabies, 2 of which occurred in California. The control of stray dogs would largely, if not completely, eradicate this disease. But other animals do become affected. Among them are cats, cows, horses, coyotes, goats, hogs, sheep, skunks, mules, and foxes[1]

The cat.—(1) As an active carrier. Cats are subject to diphtheria. (2) As a passive carrier. The habits of the cat in the city and on the farm give that animal many opportunities to secure infectious material and to distribute it.

The cow.—Beef may contain (1) bladder-worms that develop into tapeworm (tinea) ; (2) various other diseases of cattle such as foot-and-mouth disease, bovine tuberculosis. Milk may contain organisms of diseases that exist in the cow (mastitis, bovine tuberculosis, undulant fever, etc.). Milk may be contaminated by the excretions from the cow, other animals, or human beings. The sediment in a glass or bottle of milk is usually manure.

The horse.—Various diseases of the horse are transmissible to man, such as glanders.

The sheep.—Anthrax, foot-and-mouth disease.

The goat.—Malta fever, foot-and-mouth disease.

Certain fish.—Bladder-worm and tapeworm disease.

Oysters.—Typhoid.

The hog.—Trichinae, bladder-worms.

The rat.—Bubonic plague, typhus fever.

The flea.—Dwarf tapeworm.

The rabbit.—Tularemia.

[1] California State Department of Public Health, Weekly Bulletin, February 22, 1930.

The parrot and parrakeet transmit parrot disease (psittacosis) to man. (Nearly four hundred cases were reported in the world in the winter of 1929–30 with a mortality of thirty-five per cent. Pathogen not known.)

Defenses against such carriers.—(*a*) Prevent the infection of animals. Improve their sanitary and hygienic surroundings. Keep human and animal excretions from reaching them. Keep carriers of disease from them, such as rabid animals, biting insects, and human carriers.

b) Prevent the infection of humans by animals. (1) Destroy diseased animals or effectively isolate them until cured. Destroy rats. (2) Keep animal carriers away from humans. Recognize the danger of disease that may be communicated from pets. (3) Keep animal excretions away from human food, drink, and articles in common use. (4) Inspect and condemn all diseased animal foods or animal products. The Federal Meat Inspection, United States Department of Agriculture, Bureau of Animal Industry, publish the following data for the six years, ending September 23, 1912: Animals inspected at slaughter, over 321,000,000; carcasses condemned, over 90,000; parts of carcasses condemned, over 4,250,000; reinspection of meat and meat food products in their various preparations, over 37,000,000,000 pounds; condemned on reinspection, over 140,000,000 pounds; exported under certificate, 7,000,000 pounds. (5) Institute rigid sanitary measures in establishments producing animal foods—dairies, packing houses, meat markets, stockyards. (6) Institute and enforce intrastate inspection.

c) Tularemia is a disease that deserves special note because it is so very common in wild rabbits and

has been demonstrated in squirrels, wild rats, wild mice, quail, grouse, partridge, pheasants, wood chucks, muskrats, cats, and in water rats in Russia. Its known intermediary hosts are deer flies, horseflies, wood ticks, rabbit lice, bedbugs, and possibly mosquitoes..... Keep your bare hands out of wild rabbits—one per cent of them are infected with tularemia. Rabbit meat thoroughly cooked is harmless.... a temperature of 133°F. kills the infecting organism. Rubber gloves must be worn by those who dress wild rabbits....[1]

[1] *Weekly Bulletin,* California State Department of Public Health, California, November 30, 1929, quoting an announcement from the United States Public Health Service.

CHAPTER XXXVII

CONTACT INFECTION: THE DISSEMINATION OF PATHOGENS THROUGH CONTACT

The venereal diseases.—The most common and the most important contact diseases are syphilis and gonorrhea. These diseases may be carried indirectly by secondary carriers, but their most common conveyance is by direct intimate contact between the human carrier and his victim. This intimate contact is secured under various circumstances, such as:

Between husband and wife.—The numerous natural honorable and sacred intimacies that characterize the normal relationship between husband and wife make it most difficult for either one to acquire venereal disease without transferring such disease to the other.

Between parent and child.—(*a*) The contact between the father and his children is not so intimate as the contact between the mother and her children. If, however, the father has venereal disease, the mother can hardly escape, so the children will be exposed to maternal infection as well. (*b*) The infant of a gonorrheal or syphilitic mother becomes infected either before or at birth. (*c*) If the mother becomes infected after the birth of her children she may transmit her disease to her children through such intimacies as nursing, feeding, kissing, bathing, or fondling them. Such infection, if it is with the treponema of syphilis, frequently means death to the unborn babe or some physical or mental disability disqualifying and limiting it for life; if it is with the coccus of gonorrhea, it often means a blind baby—a life without eyes.

Between members of the same family in which one member has been infected.—The opportunity indicated above as existing between parents and children exists also between sons and daughters, young and old. The opportunities for such intimate contact in the home are commonly present and hard to avoid, even when such avoidance becomes seriously necessary. It is, therefore, commonly true that syphilis and gonorrhea are transferred by contact from one infected member of the family to some or all of the remaining members of the family. This transfer of infection is inevitable between husband and wife after one of the two becomes

infected and most difficult to avoid between infected parent and child, or between an infected brother or sister and the other children in the family.

Between the physician, the nurse, and the infected patient.—Many cases are on record in which the physician or nurse has become accidentally infected while operating upon or caring for a syphilitic or gonorrheal patient.

Between the carrier of venereal disease and his victim under any condition of intimate contact, as in (*a*) handling, fondling, kissing, etc.; (*b*) sexual intercourse. The most common and most important contact in this connection is that which occurs in illegitimate sexual intercourse. Every loose man and every loose woman sooner or later becomes a carrier of one or all of the venereal diseases. (Syphilis is caused by the treponema pallidum; gonorrhea is caused by the gonococcus; and chancroid is caused by a specific bacillus.) Loose moral characters of this sort are found in all parts of the world, in every community. It is not possible to estimate accurately the number of human carriers of syphilis and gonorrhea in a large city. Probably five per cent of the population has syphilis, and a very much larger per cent gonorrhea.

The venereal diseases are the most common serious communicable diseases of mankind, excepting possibly tuberculosis. These diseases are mentally, morally, and physically destructive. They are distributed by contact infection. The common and important carriers are the men and women who resort to illicit, promiscuous sexual intercourse. The man or woman who adopts such a practice must sooner or later suffer the effects of one or all of these diseases and will in all probability be responsible for conveying such disease to some other human being, who will thus become the victim—innocent or guilty—of his passion.

Respiratory diseases.—The pathogens that are excreted through the respiratory tract are distributed most frequently through contact infection. These pathogens cause such diseases as the common cold, measles, diphtheria, tonsillitis, scarlet fever, mumps, meningitis, poliomyelitis, and whooping cough. Others might be added. The "contact" necessary for infection from such sources must be intimate. It must result in the passage of pathogenic organisms from the carrier to the "victim." This may be accomplished through fondling, kissing, biting, or scratching; from passing a pipe from one mouth to another, through chewing

gum, or biting the partially eaten apple of another person; through testing the baby's bottle; chewing the baby's food before giving it to the baby; through a bite from another man's plug of tobacco; drinking from another's cup; breathing air into which someone has just sneezed, coughed, or otherwise sprayed his infected respiratory excretions. Opportunities for droplet infection are specially present in congested subway travel, movie shows, and in the life of the average infant and young child. The common bucket, dipper, sponge, and towel used by athletic squads offer an easy contact for the spread of respiratory diseases.

More rare are those contact infections in which the individual picks up specific organisms of disease through handling persons who are carriers of disease (sick or well). (1) Doctors and nurses not infrequently become infected in this manner. Such infections are not confined to any group or class of human disease carriers. The physician or nurse may become infected through contact with infected blood or tissue fluids during surgical operations. They may come into intimate contact through the administration of medicine, bathing the patient, dressing a wound, or any other of the very necessary and very important offices which they perform. Contact infection under such circumstances is due to carelessness or accident. The intelligent physician and nurse know these dangers and how to avoid them. (2) The same variety of opportunities for contact infection occurs in homes in which some member of the family is sick, especially if the family habits of personal and domestic hygiene are not good.

Contact infection may occur in large crowds where people are brought close together, as in congested subway trains, on the ferryboat, in the street car, on the elevated train, at the theater, at the moving-picture show, in the classroom, and so on. Under such circumstances, droplet infection is probably the most common variety of contact infection.

Intestinal diseases.—The diseases of the intestinal tract are usually not transferred by direct contact, although such conveyance does take place. The soiled fingers of the carrier may come into intimate contact with his victim and thus distribute to him the bacillus of typhoid fever or some other cause of intestinal disease. It is said that four per cent of all typhoid fever cases that recover become chronic carriers. The majority of these are fecal carriers. The fingers of typhoid carriers or the carrier of any other disease

organism are always dangerous and call for most careful hygiene. We have records of a number of men and women who have distributed typhoid fever in this manner for many years—as high as fifty-five years—after they have had that disease. The faucets and door knobs in public urinals offer opportunity for the transfer of organisms from the fingers of one person to those of another.

Summary.—Contact infection is the common mode of conveyance of the causes of venereal and respiratory diseases. It is less commonly the mode of conveyance of other diseases. Such conveyance may occur during the acute stages of these diseases, and under conditions of apparent health of the individual long after such diseases are "cured." These diseases may be avoided for the most part by such habits of personal, domestic, and community hygiene as will eliminate or prevent contact infection. The individual and the community would be defended from contact infection, if it were possible to have no infected contacts. Personal cleanliness is a very important protective measure in relation to contact infection.

CHAPTER XXXVIII

THE DISSEMINATION OF PATHOGENIC ORGANISMS THROUGH SECONDARY CARRIERS

Air as a carrier of disease.—Disease germs may be blown through the air by the wind. (1) The various human and animal excretions that are exposed to air may contain pathogenic organisms. These organisms may remain alive for hours, or days, or weeks, depending upon their protection from drying. If air currents set particles of these excretions in motion before the pathogens are dead, these currents may serve as carriers of disease. Flakes of sputum, dejecta, urine-soaked dust, and discharges from the sick room may qualify for such possibilities. Fortunately such possibilities are opposed by the influence of sunlight, sunheat, and dry air, all of which destroy the lives of most pathogens, after a time. (2) Certain experiments indicate that organisms of very small size may not be subject to the ordinary laws of gravity but rather to the laws that govern gases in space. If this be true, the aërial transmission of disease germs of very small size may be much like the transmission of odors of gases in the air. There are a number of diseases whose specific causes are so small that they may pass through the pores of the finest porcelain filters. They are so small that they are beyond the range of our most powerful microscopes. These "filtrate viruses" or "ultramicroscopic viruses" may be small enough to escape the laws of gravity which attract heavier bodies. They may obey the laws that govern gases in space. There are a number of human diseases the causes of which are not known. These causes may be filterable. We have no means of testing the filtrates of some of these diseases. It is possible that the specific causes of those diseases may be small enough to fall into this class. It is certain that aërial transmission of the sort that characterizes the movements of gases in space is not characteristic of such diseases as typhoid fever, tuberculosis, and diphtheria. The organisms that cause those diseases are relatively heavy. We cannot be certain that the causes of smallpox and infantile paralysis may not be spread in this manner under exceptional and favorable circumstances. But it is doubtful if any organisms are disseminated in this way.

Dust as a carrier of disease.—Dust may be a carrier of

disease only in case pathogens in dust are carried to human beings while they are still alive. Sunlight, sunheat, dry air, and other adversities kill most pathogens in minutes, hours, or days. The spores of bacteria are very much more resistant than bacteria themselves. Tubercle bacilli in sputum are protected by the viscid mucus around them. Drying may then be slow. Diphtheria bacilli in membranes from the throat may remain alive for some weeks. Pathogenic organisms in fecal masses will remain alive for short periods of time. Pathogens from any source that are excreted in dark, damp, and dirty places may become parts of dust which are not thoroughly dry. They may thus escape death for short periods. The bacillus of tuberculosis, the bacillus of typhoid fever, the bacillus of diphtheria, and the streptococci of sore throat have been found in dust. Spores of various pathogenic bacteria are found in dust. Dust may be carried by the wind to human beings, to their food, or their drink. Dirty hands and dirty utensils in common use may be infected under unusual circumstances. This may explain the fact that children are more likely to have various diseases than adults.

Water as a carrier of disease.—Families that secure their water from wells are safe from water-borne diseases from that source, provided the drainage into the well is pure. It sometimes happens that the yard privy, the cesspool, or the barnyard drains into the family well. It not uncommonly happens that communities construct water systems that draw the water supply from the same lake or river into which their community sewage is emptied. Under such circumstances typhoid fever is common. Various other diseases, notably cholera, are carried in the same way. Every community that has spent its money wisely in securing pure water has succeeded in reducing the amount of preventable sickness and the number of avoidable deaths among its citizens. This reduction is not only in typhoid fever, but in various other diseases. Fortunately, most of the pathogenic organisms are soon destroyed in water; unfortunately, nearly all pathogens will live for short periods in water. These short periods may be long enough to enable water-borne pathogens to find human victims.

Food as a carrier of disease.—*Sources of disease organisms and agents in foods.*—The food itself may be diseased and thus act as a carrier of that disease to its human consumer. Tapeworms may come from eating raw or insufficiently cooked beef, pork, or

fish infected with the cysticerci of tapeworms. Cattle may have tuberculosis, anthrax, or other disease. Food may be infected while in the hands of the producer, the shipper, the transportation agent, the wholesaler, the retailer, or the consumer. Food may be adulterated by the manufacturer or dealer who uses poisonous preservatives or other injurious adulterants.

Decomposed foods.—The fermentation of carbohydrate foods leads to the formation of acids, alcohol, carbon dioxide, water, etc. The putrefaction of nitrogenous foods, when complete, leads to the formation of ammonia, nitrates, carbon dioxide, and water. At one time it was believed that some of the intermediate products of decomposition were responsible for "food poisonings." These poisons were designated as "ptomaines." It is now the conclusion of the authorities in this field that ptomaine poisonings are acute infections with various pathogenic bacteria.

Milk as a carrier of disease.—Bad milk has been responsible for more sickness and deaths than perhaps all other foods combined, because bacteria grow well in milk; therefore, a very slight infection may produce widespread and serious results. Of all our foodstuffs, milk is the most difficult to obtain, handle, transport, and deliver in a clean, fresh, and satisfactory condition. It is the most readily decomposable of all our foods. Milk is the only standard article of diet obtained from animal sources that is consumed in its raw state.[1]

Dirty milk.—The sediment in the bottom of the milk jar or in the bottom of a glass of milk is practically always cow manure.

The organisms of certain bovine diseases will pass through the healthy udder. This is true of the ultramicroscopic virus of foot-and-mouth disease, the virus of malta fever, and the virus of milk sickness.

The organisms present in the diseased udder will likely be present in the milk, as in bovine tuberculosis and mastitis. Milk may be infected through contaminations introduced in handling by milkers and other workers who have typhoid fever, scarlet fever, diphtheria, or tuberculosis.

The diseases most commonly conveyed through milk are tuberculosis, typhoid fever, diphtheria, scarlet fever, septic sore throat, malta fever,

[1] See Milton J. Rosenau, *Preventive Medicine and Hygiene* (D. Appleton & Company, 1927), p. 696.

foot-and-mouth disease, and milk sickness; also some of the summer complaints of children and the diarrheal and dysenteric diseases of adults . . . .[1]

Raw milk is not safe milk.—The safest milk is clean, pure milk that has been pasteurized in the bottle.

Meat as a carrier of disease.—Meat taken from sick animals and meat that is contaminated on its way to the consumer may carry causes of disease to the consumer. The infectious organisms that may be transmitted thus are: (1) The bacillus enteritidis and bacillus cholera suis. (2) The bacilli of paratyphoid fever. The paratyphoid bacilli multiply in meat. (3) Trichinae. Trichinosis is a disease caused by a round worm that lives its life cycle in the hog or rat. It is communicated to man in raw and insufficiently cooked pork. (4) The pork or measly tapeworm (*Taenia solium*). This tapeworm disease is conveyed to man by eating raw or insufficiently cooked pork containing the bladder-worms (cysticerci) of the pork tapeworm. The cysticerci develop in hogs whose food has been contaminated by human feces containing the eggs of the pork tapeworm. These cysticerci may develop also in man if his food contains the eggs of the pork tapeworm. This is a very serious though rare disease. (5) The beef tapeworm (*Taenia saginata*). This organism is conveyed to man by eating raw or insufficiently cooked beef containing the bladder-worm (cysticercus of the beef tapeworm).

Fish as a carrier of disease.—Some fish are always poisonous. Some fish are poisonous only during spawning season. Fish decompose rapidly. Fish are common victims of bacterial disease. Human poisoning from this source is not uncommon. The fish tapeworm (*Dibothrocephalus latus*) occurs in human beings who eat fish containing the bladder-worms (cysticerci) of fish tapeworms. The same thing occurs in dogs, cats, and foxes that eat infected fish. Fish become infected in streams polluted by human excretions containing the eggs of fish tapeworms.

Shellfish as carriers of disease.—Poisoning from shellfish is not uncommon. Typhoid fever and cholera have been carried by oysters.

Plant foods as carriers of disease.—Some species of mushrooms are edible; others are poisonous. Potato skins contain small amounts of solanin. Very rarely this poison is present in sufficient

[1] Rosenau, *op. cit.*, p. 718.

amount to cause trouble. Green foods, such as lettuce, radishes, celery, watercress, when eaten raw, may carry the pathogens of typhoid fever, cholera, dysentery, hookworm, and various other animal and vegetable parasites which have been brought to those vegetable foods in sewage or in water contaminated with sewage.

Conclusion.—It is evident that the greater and more important part of the diseases carried by air, dust, water, or food comes originally from human sources. These various agents are infected usually through human excretions. Our problem of self-protection here is concerned with keeping human excretions from such carriers.

Summary of Disease Carriers

The human being is the most important carrier of disease. He distributes pathogens by way of his excretions—respiratory, fecal, and genito-urinary—in health and disease. His circulation may be a "reservoir" of pathogens for blood-sucking insects while he is sick or when he is apparently well.

He may transmit the organisms of disease by direct contact or through the infection of animals or insects or through the infection of articles of common use. The most important infectious relationships are secured through "droplet infection" and spitting, illicit sexual intercourse, dirty fingers, and careless disposal of excretions.

The most important insect carriers are the fly, mosquito, flea, and louse.

The most important animal carriers are the cow (by way of her milk), the rat, and the dog.

The most important food carriers are milk and infected meats.

Unclean, impure water is a common and dangerous carrier.

If health is to be protected, it can be done only by a successful defense against (*a*) persons who are sick; (*b*) careless humans who "hawk" and cough and spit without regard for others; (*c*) men of loose morals; (*d*) prostitutes; (*e*) post-febrile carriers (particularly after typhoid fever); (*f*) impure milk and bad water; (*g*) the fly, the mosquito, the flea, the louse; (*h*) the rat and the dog.

CHAPTER XXXIX

PRINCIPLES OF DEFENSIVE MENTAL HYGIENE

Meaning of mental disease.—It is unfortunate that common opinion regards mental disease with a suspicion that it always means insanity; that if one is mentally sick, he is necessarily crazy. As a matter of fact, this is far from true. The term has a much broader meaning and should not invite the belief that it means any more than any other classification of health disturbances. Mental disease includes transient nervousness, temporary anxiety, momentary mental discomfort or distress (dis-ease) of any sort. It includes, also, disturbances of a longer or permanent duration and of more severe effect, even to profound dementia or mental deprivation. A mental disease should not be a thing to be ashamed of. If all the milder exhibitions of mental disease could be frankly brought to the attention of competent health advisers, much unhappiness and social maladjustment would be avoided and the number of cases of severe and permanent mental damage would be very enormously reduced. If this were the common practice, it would result in a better knowledge of the determining, contributory, and exciting causes of mental disease and would ultimately furnish a scientific basis for their more effective prevention, better care, and more frequent cure.

A mental disease is a transient, temporary, or lasting exaggeration, depression, distortion, disintegration, defect, or deprivation of mental functions, ranging from slight inconsequential disturbances to extreme and permanent mental disabilities. Exaggerations are present in such states as (1) nervousness, restlessness, or other excitement; (2) depressions, as in the "blues," low spirits, gloominess, brooding, or melancholy; (3) distortion, as in anxiety, apprehension, indecision, or doubt; (4) disintegration, as in misinterpretations, illusions, delusions, hallucinations, walking in one's sleep, or other dissociation of personality; (5) defect, as in the defects of intelligence and lack of educability, as in the moron, the imbecile, and the idiot; and (6) deprivation, as in the paralysis and anaesthesias of psychic origin characteristic of "shell shock" and other hysterical manifestations.

The causes of mental disease.—Our knowledge of the causes of mental health injuries has been very materially increased

within recent years. The future promises a much greater understanding. Our present knowledge enables us to classify the causes of mental diseases as follows: Group One, pathological heritage and heritage of susceptibilities to mental disease; Group Two, poisons of internal origin and of external origin, the toxines of infections, and the effects of exhaustion and starvation; Group Three, acquired organic changes in the central nervous system, such as traumatic injuries, destructive infections, and the degenerative influences of hardened arteries (arteriosclerosis) and of senility; Group Four, the psychic (psychological) causes with which there is as a rule no demonstrable associated structural (i.e., anatomical or organic) change.[1]

The psychic causes of mental disease.—With the exception of the last group, the nature of these causes has been discussed in other chapters of this book. The psychic causes of disease have received only incidental mention, as, for instance, in the chapters on play in Part I and Part II. They are the least understood of all the causes of health injury. The psychic causes of mental disease are easily confused with the psychic effects—i.e., the psychological disturbances—they produce. They cause mental disease in susceptible individuals. There is good reason to believe that susceptibility or vulnerability to the psychic causes of disease is a product of heredity and that psychic causes are not effective except in the individual who has a heritage of susceptibility.

Among the psychic causes that are now recognized as contributing to the production of mental disease or as possibly precipitating mental disease, there are the following that may be listed:

The personality of the "spoiled child," the coddled mind characteristic of the only child, feeling of superiority, the personality that is unable to adapt itself to its social environment, being alone, solitariness, selfishness, envy, jealousy, failure, feeling of inadequacy or inferiority, and of lack of self-confidence.

The shock of a tragedy, as of a terrifying or hideous experience; lack of emotional control; emotional excesses; conflict of desires, appetites, urges, yearnings, longings, and ambitions with opposing standards of ethics, beliefs, or mores; conflicts between firm beliefs in what is right and persistent urgings to do what is believed to be wrong; the desire to escape unpleasant reality.

[1] See Appendix B for description of these groups in some detail.

The effects of health injury are listed below. They, in turn, may become causes of further health injury, establishing a vicious circle.

The effects of mental health injury.[1]—The following list of symptoms gives evidence of injured mental health. The injury may be transient and inconsequential. It may be mild and soon pass away, or it may be of longer duration or permanent. The symptoms of mental injury are correspondingly momentary, transient, or permanent. They are evidenced in deficiency or absence of normal mental or nervous functions, or in their exaggeration, maladjustment, or depression. The decision that a given mental or nervous behavior is evidence of important mental disease can be safely made only by a specially scientifically educated and experienced physician.

This list of symptoms of injured mental and nervous health is generally descriptive. It will be of value to the reader only as an aid to his better understanding of the scope of mental health, mental disease, and defensive mental hygiene. It is not to be regarded as a basis on which one may diagnose his own mental disturbances or the mental disturbances of others without the aid of a carefully and appropriately chosen responsible medical examiner. One makes a serious mistake when he permits his interest in the symptoms of disease to lead him to the belief that he is a victim of such disease and then worry about it.

List of symptoms giving evidence of transient or permanent, inconsequential, or serious injuries of mental health.—Unhappiness, cheerlessness, loneliness, homesickness, shyness, unsociability, unfriendliness, inability to get along with other people, fault-finding, quarrelsomeness, suspiciousness, irritability, hostility, cruelty, social and moral delinquency, anti-social behaviors, suicidal and homicidal tendencies and acts.

Restlessness, agitation, sleeplessness, fatiguability, rapid exhaustion and prostration out of proportion to cause, inability to pay attention (distractibility, lack of concentration), excitement, lapses of memory, apprehensiveness, anxiety, fear, paralysis or anaesthesias without demonstrable organic cause, impotence, depression, apathy, indecision, confusion, lack of self-control, irresponsibility, foolish actions, unreasonableness, stubbornness, ir-

[1] See Appendix B for a somewhat detailed discussion of the causes and symptoms of mental disease.

rationality, illusions, delusions, hallucinations, compulsions, obsessions, and phobias.

"Flight of ideas" (over-talkativeness—incessant talking, giving expression to an endless succession of apparently unrelated thoughts and never coming to a conclusion), emotional exaltation, over-activity (motor), delirium, difficulty of thinking, psychomotor retardation, emotional depression, and melancholia.

Morbid introspection, delusions of persecution more or less elaborately described in a systematic, defensive way by the patient, and dissociation of personality.

Defective intelligence and lack of educability of different degrees, such as (1) the low-grade idiot who may not be capable of learning even to attend wittingly to the calls of nature; (2) the imbecile who may have capacity to learn to take some care of himself but never to the extent that he can with any independence; (3) the moron who may be able to learn enough to live more or less independently under favorable conditions.

Congenital conditions that cause injury to mental health.—The adversities of unfavorable prenatal environment may prevent the normal or complete development of the brain of the growing embryo or fetus. Or this influence may result in a functional rather than a structural damage and contribute, therefore, to the birth of a child with a mental and nervous hypersensitiveness to the causes of mental health injury.

These adverse congenital conditions may be due to unfavorable prenatal mechanical, physical, or chemical environment. Thus, the infant may be born with a heritage of a defective brain or with a defective brain produced by an adverse prenatal environment. Or the infant may arrive with a heritage of, or an acquirement of, mental and nervous susceptibilities to the adverse influences of later life. These adverse influences may be deficiencies or defects in the essentials for health or life. They may be mechanical, physical, or chemical causes of disease. They may be pathogenic organisms. Or they may be psychic (i.e., mental or psychological) causes or they may be social causes.

The psychic causes of mental disease that operate in infancy and childhood.—This period of mental development is the period of greatest hazard to the future mental health of the individual. His mind develops in response to the stimulations of his social experiences with his mother, father, brothers, sisters,

playmates, and all others who belong to his family group, his play group, his gang, and his school group. If he goes to work early, he falls early under the influence of his group associates and competitors—paper carriers, messenger boys, bell hops, caddies, etc. It is in this period that he imitates the example set by those about him in his attitudes of mind, his habits and behaviors. Most of these earlier years are devoted to play. It may not be the intention of his parents or teachers that his life should be one of play, but the motivations of the play urge will influence him and his conduct regardless of the intentions of his elders. We noted the supreme importance of this experience in an earlier chapter.

If the adults about him are examples of obvious mental and nervous irritability and excitement or of depression and seclusiveness, he may carry a permanent record of his exposure to their influences. His family, his playmates, gang, and schoolmates may fix in his personality attitudes of selfishness, envy, jealousy, and cruelty, with habits of emotional excess expressed in fits of anger and rage. Or his experiences may fix in his mind an attitude of fear or self-abnegation. He may learn that by an exhibition of tantrums he gets what he wants.

The psychic causes of mental health injury that are associated with adolescence.—The periods of childhood and adolescence and of adolescence and early maturity overlap. But adolescence is a distinct and tremendously important stage in the growth and development of the individual. It is the time for the rapid structural and functional growth and development of the generative organs. Adolescence brings the realization and stress of sex. It is also the period in which the intelligent mind begins a serious use of its educational development. Somewhere between childhood and maturity the youth begins to try to think, reason, and decide, and to act wittingly. Finally, this is the period of conscious, or at least more conscious, sociability. The adolescent really discovers or begins to discover other young men and other young women—other people—and to be understandingly conscious of social relations.

The habits and attitudes of mind developed in infancy and childhood are subjected to the stresses of these new realizations that come with puberty, youth, and maturity.

To appreciate the possibilities of this time of life in the way of mental deterioration we have only to call to mind the unusually rapid growth of

the organism in every tissue, the new and powerful activity of all the functions, especially those of nutrition, in the progress toward complete development, and the stamina and often the care that are essential for properly meeting the demands of this revolutionary period. The disturbance of the heretofore tranquil nervous system by the advent of the reproductive functions is a vital change, and the proper adjustment of this part of the organism to the working whole is of far-reaching importance, as the genital activities have a profound effect on the entire system and the developing personality. During adolescence the normal mental condition is not a solidly settled one, and at this time, if ever, should we expect to find pathological disturbance when impressionability, instability of purpose, variation of mood, excitability, impulsiveness, ambition, independence, and intolerance are most likely to be in full play; when the affections, emotions, and newly awakened sexual feelings and passions are most keen; when reflection and judgment are immature; and, above all, when self-control, which should regulate all, is itself in an imperfect stage and in danger of being unequal to its function.[1]

The psychic causes of mental health injury during adult life.—Each preceding age period may and frequently does contribute an unfavorable influence upon the mental health of the individual in his succeeding age period. The physical and mental experiences of infancy, childhood, and adolescence furnish maturity with a resource of health or with a hazard of disease. This is particularly true of mental health and mental disease. That tens of thousands of new mental cases are admitted to our hospitals every year and that one person out of every twenty-five in the aggregate eventually exhibits mental health injuries of sufficient importance to raise the question of hospitalization are facts very largely of adult life.

During this period the psychic causes of disease are present in such situations as the following:

1. In the difficulties that arise when a selfish personality that has always had its own way as an infant and child, on reaching maturity, attempts group life with individuals who are not interested in letting him have his own way.

2. In the case of the man or woman who arrives at maturity with a compelling attitude and habit of timidity and a conviction of inadequacy.

[1] Henry R. Stedman, M.D., *Mental Pitfalls of Adolescence* (The National Committee for Mental Hygiene, 1922), p. 6.

3. When failure and disappointment seem to destroy all hope of success.

4. When occasions for fear, anxiety, worry, or depression arise.

5. When shocked by bereavement, faithlessness, or disloyalty.

6. In the mental discord that comes with the struggle between ideals and standards on the one hand and unworthy behaviors on the other; the conflict between loyalties and ethics; or the battle between the urge to do the right thing and a longing to do a wrong thing.

The preventability of mental disease.—Our knowledge of the causes of mental disease furnishes the principles on which programs or policies for the prevention of those diseases may be confidently planned. If a cause may be eradicated, the disease it causes may be prevented. If the cause may be controlled, the disease may be prevented. If the individual may be protected against a cause, the disease may be prevented.

Our discussion of the known causes of mental diseases makes it clear that theoretically, at least, they are preventable. In so far as it may some day be practical to identify and control the matings of carriers of dominant or recessive pathogenic genes that cause mental disorder or deficiency or nervous instability in the children born of such parentage, it will be possible to prevent the heritage of mental disease. This is one of the tasks to which eugenics has set itself. In so far as we learn to educate the developing, intelligent mind of infancy and childhood so that it will arrive at maturity in a state of normal health represented by a sociable, self-respecting, self-controlling personality, we will be able measurably to prevent the acquirement of mental disease from psychic causes in adult life.

The prevention of mental diseases from psychic causes is probably more practical than their prevention from hereditary causes. This is essentially a problem of family and other group life. Unfortunately, the home group, the play group, and the school group are not as yet very effective in their preventions of mental disorders due to the psychic causes of mental diseases that are always present and hazardous in group life.

Defenses against the psychic causes of mental disease.—The purely psychic causes (i.e., the mental or psychological causes) of mental disease that were listed above may be redescribed as con-

flicts or collisions between dynamic motivations chiefly, if not wholly, of elemental instinct mind on the one side and powerful self-controls exercised by educated intelligent mind on the other.

The prevention of mental disease from psychic causes is a problem of education of intelligent mind for the purpose of securing among other things a wise and powerful control over the emotionally charged urges and longings that characterize instinctive motivations. The defense of mental health against the psychological causes of mental disease consists in exercising that control effectively.

This problem is obviously primarily one of education of the infant, child, and adolescent mind through an appropriate provision and management of favorable physical, biological, and social environments. The principles of preventive mental hygiene that are to be applied in these age periods for the later prevention and control of the psychic causes of mental disease are not as yet satisfactorily known. We know that the infant and child learn by observation and imitation, by response to satisfying experiences, by instruction, and by obedience to command. Beginning with a heritage of normal mind and given a favorable group environment containing normal minded people, the development of the educable mind will probably be normal.

The most important educative environments in these periods are the social environments formed by (1) the family group; (2) the play group; and (3) the school group. The strongest preventive mental hygiene that may be exercised by the group is present in the attitudes and habits of the parents and other group leaders. Their obvious personality traits are imitated by the younger, immature, impressionable members. The behaviors of parents and other group leaders, mature or immature, are educational influences, good or bad, upon the developing minds in their groups. Their deportment may be educative examples of emotional control, mental calm, and healthful cheerfulness, happiness, and joy. Their management of the internal and external environment of their groups may successfully prevent the appearance of damaging environmental psychological (psychic) causes such as tragic scenes, harrowing experiences, cruelty, fighting, nagging, injustice, teasing, embarrassment, shame, temptation, idleness, coddling, and lack of opportunity for mentally healthful social play.

Obviously, the individual hygiene of parents and of other leaders of children constitutes the most important possibility of producing and safeguarding the mental health of the child and, through the child, the self-defending mental health of the man or woman that the child is to become. In other words, the mental health and the defense of the mental health of the adult of tomorrow depends on the mental health habits of parents and other leaders of children today.

Finally, it is apparent that the defense of mental health is a joint problem of individual hygiene, group hygiene, and societal hygiene. The principles that have been discussed in this chapter furnish a basis on which the practice of defensive mental hygiene may hopefully be developed.

CHAPTER XL

ENVIRONMENT AND OTHER CONTRIBUTORY CAUSES OF DISEASE

Definition.—A contributory cause of disease is an influence that makes it easier to lose health or be sick and harder to get well or regain health. Anything that favors a cause of disease or weakens a defense against disease, or exposes an individual to health injury, is a contributory cause of disease.

The preceding pages of this text on defensive hygiene have been concerned with specific or determining causes of disease. We are now considering the influences that favor those specific or determining causes and thus act as contributory causes of disease. The contributory causes of disease may belong to the internal environment of an individual, or to his external environment, or both. We have defined the meaning of internal and external environment in our earlier discussion of defenses against environmental deprivations and deficiencies (see pages 266 ff.).

Unfavorable internal environment as a contributory cause of disease.—An internal environment is composed of the cells, tissues, and organs, and their content, and their structural and functional relations that in the aggregate constitute the individual. An internal environment is unfavorable when some detail of its structure, function, or content serves as a contributory cause of disease. An unfavorable internal environment may be due to (*a*) unfavorable structural and functional heritage; (*b*) congenital defects; (*c*) defects acquired later; (*d*) vulnerabilities from age; (*e*) vulnerabilities from sex; (*f*) idiosyncrasies (individual differences); (*g*) after-effects of acute disease; (*h*) chronic disease.

Inherited unfavorable internal environment.—In our chapter on the defensive hygiene of heredity we noted some heritages that are distinctly heritages of specific disease. In addition, we noted heritages of tendencies to certain specific diseases. In the consideration now before us we are concerned with the fact that these may be organic, physical, chemical, or functional details in the heritage of an individual that contribute to his poor health or disease, or delay or prevent his recuperation or his recovery of health after illness.

If the individual could select his ancestors there is a possibility that he might select wisely. He might arrange to be well-born. He might secure a "strong constitution." His choice might give him a heritage of perfect organs and balanced physiology that would supply him with a fundamental basis for the development of vigorous, enduring mental health, physical health, and social health.

This speculation is absurd, but it serves to emphasize the cruelties of thoughtless parentage. Enormously more attention is paid to the breeding of superior horses, cattle, dogs, and other domestic animals than to the production of even normal human offspring. As we noted above, the inheritance of specific diseases is discussed in another chapter. In addition, we know that heredity not infrequently manifests itself in the form of subnormal resistance to the agents that injure health, or in the form of tendencies to certain infections, or as mental instabilities that yield to the shock of unusual experience. Heredity is, therefore, an important contributor to poor health. The chief of its contributions may be stated as follows:

There is a typical heritage of feeble body that is made up, in its obvious composition, of small bones, puny muscles, "weak" lungs, and general structural and functional inadequacy. Such a physical organization achieves health with difficulty and succumbs more easily to the inanimate and animate causes of disease.

Most of us have inherited at least one organ or tissue that yields with abnormal readiness to agents that injure health. These are vulnerable points in our defensive armamentariums.

Certain family histories disclose a family tendency to infections of the mucous membrane lining the nose, throat, and ears.

We recognize an inherited predisposition to tuberculosis.

Syphilis is not inherited as an infection but its damage may be passed on to successive generations.

Alcoholic parents do not transmit their thirst to their children but they do give them a heritage of physiological weakness, developmental imperfections, and nervous deficiencies and instabilities that make health, service, and happiness difficult or impossible.

Nervous and psychic instabilities are often products of heredity. Since the heritable nervous and psychic diseases are the most important of the specific hereditary diseases, so the heritable nervous and psychic instabilities or disease tendencies are the most

important of the constitutional contributory causes of disease. The stress of a powerful shock may force the appearance of one or more prominent nervous, mental, or moral disorders in the heir to such a legacy of instability. "Shell shock" is not peculiar to war. The array of nervous and psychic disorders that grew out of the war has only emphasized the end-results of a group of nervous and psychic instabilities that are always with us. Peace with its inbreeding, its alcohol, its syphilis, and its other germ-cell poisons furnished the instabilities. The war supplied the shock.

The details of heredity and of eugenics furnish problems for the patient, scientific investigator. The responsible citizen has neither time nor need for an intimate knowledge of those details. But his obligation to himself and to his posterity demands that he understand the merciless natural forces involved. The college student for whom this text is primarily intended is a specially favored citizen, and is under even greater obligation to recognize the probable and possible health problems in his heredity. These problems for every citizen are (*a*) those arising from his own heritage; (*b*) those which he may pass on to his children. Every individual with an intelligent mind has a large control over (*a*) and a larger control over (*b*).

Unfavorable internal environment acquired congenitally.—The period in the life of the individual from conception to and including his birth is his congenital period. Injuries acquired during this period are known as congenital injuries. These injuries to the internal environment of the individual are products of unfavorable external environment furnished by the expectant mother. It is difficult and often impossible to distinguish between structural or functional damages that are acquired congenitally and those that are inherited. We know that the following are samples of a long list of known injuries acquired congenitally that are unfavorable to the good mental, physical, or social health of the individual: cleft palate; hare lip; absence of parts, such as a hand or arm; certain abnormalities of the heart; imperfect kidneys; defects of the brain or spinal cord or nerves; and deficiencies of the mind.

Individual differences in internal environments as contributory causes of disease.—Peculiarities of internal environment exhibiting various vulnerabilities to disease may be inherited or they may be acquired. The identification of their sources may be im-

possible. The important fact is that individuals differ greatly in their susceptibility to poor health and disease with often no evident reason for the idiosyncrasy. Thus, exposures to the deficiency causes of disease, or to physical, chemical, or mechanical causes, or to pathogenic microbes may disclose an unusual and unexplainable lack of resistance or an equally unaccountable resistance to their damaging influence.

Post-natal defects of the internal environment.—Structural and functional defects unfavorable to subsequent health may be established at any time after birth. Any of the specific causes of disease discussed in the preceding chapters of this book may be followed with a slow recovery, or leave the individual permanently debilitated and an easy victim of other causes of disease. A more or less permanently unfavorable internal environment favoring poor health may thus be produced in consequence of attacks of acute disease. Measles, tonsillitis, scarlet fever, pneumonia, syphilis, and other acute infectious diseases are known to leave damaged organs and weakened functions.

These facts constitute a strong argument for the adequate scientific treatment of all cases of acute disease from any cause.

Age as a contributory cause of disease.—Age is a condition of the cells, tissues, and organs that constitute internal environment. Infants, young children, the youth, and the aged are more vulnerable to disease and injury than people of early maturity and middle age.

The helplessness of the infant exposes it to health penalties arising from the ignorance, misinformation, carelessness, poverty, and neglect of those upon whom it depends. Infant mortality is excessive in all parts of the world. Infant morbidity is worse. The babe or the young child is wholly subject to the group and community hygiene under which it lives. It has no individual hygiene. Therefore, infant morbidity and infant mortality rates are indices of the intelligence and effectiveness of family and community hygiene. A high infant death-rate comes with a low social scale. Childhood and youth are periods of decreasing dependence. With an increase of education, judgment, and information the growing human develops his policy of personal health control. He establishes his own program of conservative and constructive individual hygiene. Meanwhile, he is subject to the inadequacies and fallacies of the group and community in which he lives.

The infant and the young child are, in addition, structurally and physiologically less resistant to health injuries than the mature person. They are more easily and more seriously damaged by under-nourishment; by lack of developmental physical activity; by cheerless, joyless living; by inadequate sleep; and by the effects of disease.

The dependence of old age is in some respects similar to that of infancy and childhood, but a comparison of the organism in old age will show that there is not an organ or tissue, not a function, mental or physical, identical at the two periods of life.

The young are more susceptible to infectious diseases. The eruptive diseases of early life are rare in the aged, and other bacterial diseases are milder.

The child can stand short changes in temperature, atmospheric pressure, environment, and mode of life better than the aged. Recovery from acute disease is more rapid and more complete in the young. Permanent impairment or slow recovery to normal senility occurs in old age after acute disease.

Young children are more liable than adults to whooping cough, measles, chicken-pox, smallpox, meningitis, infantile paralysis, bronchopneumonia, diphtheria, scarlet fever, and mumps. The chief diseases of old age are lobar pneumonia, Bright's disease, arteriosclerosis, heart disease, and cancer.

Sex as a contributory cause of disease.—We have noted in our discussion of the hygiene of heredity that the chromosomes of the male differ from those of the female at least so far as the presence of the Y-chromosome is concerned. It is possible that this structural difference may account for certain differences between women and men in susceptibilities to disease, as, for instance, nervous diseases in general and cancer in particular.

Because of the part she plays in the continuity of human life and because of a common and careless neglect of her precious function woman must often regard her sex as a contributory source of her poor health. The accidents and neglects of pregnancy and labor have brought invalidism and death to many mothers. There is no other function of human beings that is more honorable and more important than motherhood.

Modern scientific medical education has in a large part eliminated the dangers of childbearing. The woman who brings a new life into being deserves all the care and protection science can

give her. The father, the home, and the community are under a very heavy obligation to see that she gets this safeguarding care and protection.

Because of the satisfaction that she can give man's sexual passion woman is often victimized by men searching for this satisfaction. As a result she often suffers the moral, social, and psychic injuries of illegitimate motherhood. She may become diseased. If she becomes promiscuous, she cannot avoid infection sooner or later with gonorrhea or syphilis or both. There is no more pathetic or tragic picture in all hygiene than that of the women and girls that have been sacrificed morally and physically in man's unscrupulous search for sexual satisfaction.

Because of the gross structural anatomy of her internal reproductive organs and because of the physiological activity of those organs women are very liable to painful periods of menstruation. These painful periods may yield to careful habits of rest and exercise or to wise medical attention. Neglected, they have a tendency to general invalidism.

At about the age of forty-five, the average woman undergoes a very profound sexual change. Her menstrual periods cease. She can no longer bear children. For a period of several years she may be in a condition of psychic or nervous instability. At such a time the shock of a dramatic or tragic or very unusual emotional experience may easily disturb her profoundly and establish mental or nervous disease.

It is obvious that the sex lives of our girls and women deserve special consideration and intelligent scientific care. Healthy wives and healthy mothers are essential to the continuity and vigor of the race.

Women have a greater susceptibility to cancer than men; also to various nervous diseases. One woman in every seven past the age of forty-five dies of cancer; one man in every ten. Half-yearly examinations and early treatment are of the greatest importance for the prevention of cancer.

Men are more commonly affected than women by diseases that are favored by occupational influences, exposure, alcoholism, sexual excesses, and other forms of dissipation. These may then be said to be the contributory causes of diseases which are prominent with men.

In this group of contributory causes, sexual excesses is the

most important in its influence upon the health of men. Promiscuous sexual intercourse commonly leads to disease. There is not only a consequent destruction of moral and spiritual health; there is in addition the gross and subtle physical and physiological wreckage of gonorrhea and syphilis. The promiscuous satisfaction of the sexual urge commonly invokes a fearful penalty. The pressure of the sex impulse is normal in the healthy, vigorous adolescent and adult. But the experience of civilization and the facts of physiology establish the wisdom and the health benefit of extra-marital continence and of intra-marital sexual temperance.

It is taught by some students of psychology and psychiatry that a large proportion of our mental and nervous diseases is due to a suppression or repression of the sex impulse. By means of psychoanalysis these investigators seek to determine the particular suppression or inhibition that is in causal relation to the mental or nervous abnormality presented in a given case. Among the developments of this theory is the recommendation of extra-marital satisfaction of the desire for sexual intercourse. Such advice is exceedingly dangerous. It is extremely doubtful that the "benefits" of sexual intercourse outside the married relationship ever, under any circumstances, balance the damages of syphilis and gonorrhea, the loss of self-respect, the unhappiness of regret, and mental conflicts of similar nature that are consequent on promiscuity.

Unfavorable external environment as a contributory cause of disease.—The body of the expectant mother constitutes the external environment of the unborn child. The animate and inanimate world that surrounds him is the external environment of the individual after birth. His dwelling, community, habitat, geological and geographical, zoölogical and botanical surroundings constitute his external environment. From birth to death his external environment is a combination of physical, biological, and social environment. The physical environment is furnished by the atmosphere, the light and heat of the sun, distance from equator, altitude, geology, geography, water supply, rainfall, and climate; by community provisions of illumination, heat, water supply, and legal regulations of architecture and building construction; and by the dwelling house and its equipment and furnishings supplied by the group of which the individual is a part.

The biological environment is constituted by the vegetable and animal life (botanical and zoölogical) of the neighborhood and by their food products.

The social environment is constituted by people, their ways of living, their beliefs (folkways and mores), customs, laws, and institutions.

A favorable external environment is requisite to health and to life. An unfavorable physical or biological or social environment may make health difficult or life impossible.

Unfavorable prenatal external environment.—During the prenatal period, the growing human embryo may be injured or diseased through serious injury, disease, or poor health of the mother. This injury may be accomplished by overwork of the mother, rough treatment or insufficient nourishment of the mother, leading to weak, puny, or non-resistant offspring, or even to the birth of a dead infant. Maternal heart disease, kidney disease, syphilis, and other diseases of similar importance may bring about these results.

Poisons like alcohol, lead, mercury, arsenic, carbon monoxide, and morphine easily pass from the circulation of the mother to that of the unborn child.

Alcoholic women, and women who are poisoned by lead, may be unable to bear live children; or may lose them soon after birth; or may bear idiots, imbeciles, and epileptics.

Infectious diseases do not often pass from the mother to the fetus, but such transmissions do occur. There are recorded cases of fetal infection with syphilis, tuberculosis, smallpox, chickenpox, measles, scarlet fever, erysipelas, septic disorders, acute rheumatism, typhoid fever, cholera, cerebrospinal meningitis, influenza, mumps, relapsing fever, malaria, and yellow fever. The list is a long one but the number of cases on record is small (Adami).

The influences in its external environment that may lead to injury of the unborn infant as described above may be classified as (*a*) physical or mechanical; (*b*) nutritional; (*c*) toxic; (*d*) infectious.

The most important source of acquired injury to the unborn infant is syphilis. The most important source of injury at the time of the delivery of the infant is gonorrhea. Both diseases are avoidable and their occurrence is a responsibility of one or both parents. Syphilis is a cause of death to the fetus. It often pro-

duces sick, weak babies that have not even a sporting chance in the battle of life. Gonorrhea frequently affects the eyes of the infant a few hours after birth and is a common cause of partial or complete blindness. With ordinary care at the natal moment, this life-long punishment of the infant for an accident or neglect of a father or mother may be avoided.

It is obvious that a great deal of physical and physiological imperfection and inadequacy would be saved the children of the race if the average parent had a rational knowledge of the simple unalterable relations between cause and effect in health and disease, and for that reason had provided a carefully chosen competent medical service for the periodic examination, advice, and care of his family and himself.

Unfavorable external environment at childbirth.—Childbirth not infrequently exposes the infant to physical or mechanical injury, or to contact infection. It occasionally happens that the life of the infant must be sacrificed to save that of the mother. This situation is rare and is usually the result of natural interferences with the normal delivery of the child that could have been foreseen and managed without loss of life or health if careful repeated examinations had been made during the prenatal period. More commonly it is necessary for the physician to assist the birth by manual or instrumental measures. These procedures save many lives, both of mothers and infants, but they are occasionally accompanied by physical injuries of more or less serious importance to the mother and to the child.

The most common and the most serious infection of infants at this time is gonorrhea. Less common infections are from various pus organisms. Gonorrhea in the newborn is usually located in the eyes. Fortunately, this serious infection is becoming less common, but it is probably even yet fair to state that more infants are made blind in this than in any other way. Thus the infant suffers because of the careless hygiene of its parents.

The prenatal period and the period of birth are, then, periods of hazard that may easily become contributory causes of disease. They are periods in which the hygiene of human life requires special forethought and care. The overworked mother, the underfed mother, the sick mother, must necessarily fail to protect and to nourish her unborn babe adequately. Responsibility for such failure must rest upon the father quite as much as the mother.

This responsibility is often a responsibility of society itself. The community regulation of the external environment of women at work is of great importance in those occupations which stamp their damage upon the power of motherhood and on the vitality of offspring.

It must be obvious, too, that the unborn babe and the babe at birth are often made to suffer in punishment for the unhygienic habits of either or both parents. The various infections, particularly those of syphilis and gonorrhea, figure especially in events of this sort.

Unfavorable external physical environment as a contributory cause of disease.—*Unfavorable climate.*—The combined influences of sunheat, sunlight, atmospheric pressure, humidity, and electricity produce climate. An even, monotonous climate is not favorable to physiological efficiency. Constant very low temperatures are physically depressing. Constant high temperatures associated with high atmospheric humidity make heavy demands upon the heat-regulating organs of the skin, the lungs, and the circulation of the human body. Such combinations of unvarying high temperature and humidity are characteristic of certain tropical climates. These influences produce fatigue upon slight exertion. Under such climatic adversities it is not possible to maintain vigorous nervous and muscular condition. Physical and physiological deterioration are, therefore, the inevitable hazards of prolonged tropical life. And mental and moral degeneracies are easily and commonly consequent.

Climate is modified by distance from the equator, elevation above the level of the sea, and distance from the sea. It is further modified by ocean currents, prevailing winds, mountain ranges, and inland bodies of water. Daily, monthly, and seasonal climatic variations, within limits, are favorable to physiological efficiency. Bracing, stimulating, and invigorating climatic, seasonal, and weather variations are important factors in conservative and constructive hygiene. The North Temperate Zone in the neighborhood of the fortieth parallel of latitude is the world's region of greatest variation in these atmospheric influences and it is the region of man's greatest achievements in all lines of human progress.[1]

Tropical climates are notorious for the variety and severity

[1] Ellsworth Huntington, *Civilization and Climate* (Yale University Press).

of their parasitic diseases. These warm, moist regions encourage the reproduction of animal and vegetable life and favor the growth and vitality of many pathogenic organisms that are not found or not commonly found in cold or temperate climates. For instance, the hookworm is found between 36 degrees north latitude and 30 degrees south latitude in a belt that goes around the world. Tropical malaria is not commonly found in temperate climates. The parasite is found only in warm climates. Those climates that furnish warm, moist conditions offer influences under which disease carriers as well as pathogenic organisms multiply abundantly or remain alive and active for longer periods of time.

The unfavorable influence of seasons.—(*a*) Respiratory diseases are more common in winter than in summer. This may be due to the fact that human beings are more likely to stay in the house and are, therefore, in closer and more intimate contact with each other during cold weather. This social relation favors the distribution of disease germs. (*b*) The intestinal diseases are more common in summer. Warm temperature prolongs the life of pathogenic organisms in infected food or water. Pathogens that reproduce in nature multiply more profusely in warm weather than in cold weather. (*c*) The insect carriers of disease breed more abundantly in the summer months; for example, mosquito life is most favored in the warm, moist seasons of the year; flies are produced abundantly throughout the summer; the spring and the fall are the seasons for pollen diseases—hay fever, rose cold, etc.; spring rains and spring thaws are seasonal occurrences in some countries. These seasonal freshets often wash infectious surface accumulations into reservoirs and other sources of water for human consumption. Under such circumstances there are characteristic epidemics of various diseases (notably typhoid), the occurrence of which is very greatly reduced through scientific protection of the water supply. Every city that has spent its money wisely for pure drinking water has reduced the occurrence of disease among its citizens.

Unfavorable influence of weather.—(*a*) Lack of sunshine and excess of fog contribute to the increase of disease. The organisms of disease live longer under such circumstances. More people die in London during foggy periods than during clear periods. Such weather probably has a depressing effect on human vitality. (*b*) High and low temperatures are contributory causes of cer-

tain diseases (climatic, seasonal, geographical). We have noted, for example, that there is an increased morbidity and mortality from intestinal diseases in hot weather. Increased morbidity and mortality from respiratory diseases occur in the cold weather. (*c*) Exposure to wet or cold, especially to wet and cold, particularly if prolonged to the point of exhaustion, is often a contributory factor in the causation of respiratory disease, notably pneumonia.

Great natural physical calamities.—History carries many records of disasters from famines, floods, fires, earthquakes, volcanoes, and tidal waves that demonstrate the damaging effects of such events upon hygiene and, therefore, on health. Any extensive destruction of property is likely to be accompanied by starvation, under-nourishment, and physical incapacity and by a demoralization and paralysis of local governmental machinery which results in epidemics, lawlessness, and crime. These are the occasions when the world comes to the rescue of its sufferers. The cities of Europe buried in volcanic ashes, the great Chicago fire, the earthquake and fire of San Francisco, the tidal wave of Galveston, the floods of the Ohio and the Mississippi, the "cloudburst" of Pueblo, and the famines of Ireland, China, and Russia are samples of great disasters in which human health and human life are heavily sacrificed. The amelioration of suffering consequent upon such calamities is one of the functions of societal hygiene. Such agencies as the American Red Cross are organized and prepared, among other things, to manage great programs of relief with speed and completeness.

It is of obvious importance that men and women should be informed concerning the relations of cause and effect that inevitably exist between the devastation and destruction of great calamities and the want, misery, suffering, sickness, and death that will follow them in the absence of rapid, organized relief. And it is equally obvious that these problems of organized relief are problems that call for the best education and the highest intelligence for their effective solution.

Unfavorable external biological environment as a contributory cause of disease.—Life, whether it be plant or animal life, depends on favorable physical environment. Biological environment, therefore, depends upon physical environment. Any biological environment that favors the reproduction or mainte-

nance of plants or animals which injure human health is an environment unfavorable to human health unless it is brought under control. Any environment that is poor in vegetable foods or animal foods is an unfavorable biological environment.

Combinations of atmospheric, land, and water conditions determine the distribution and abundance of vegetable and animal life. These influences in nature produce the jungle swamps of the tropics with their teeming plant and animal life. Tropical malaria, hookworm disease, the snakes of India, the sleeping sickness of Africa, the tick fever of Northwestern United States are examples of distributions governed by physical geography.

Rocky Mountain spotted fever (tick fever) seems to be confined largely to the Rocky Mountains and high plateaus of some of our Western states. This limitation of the disease may be due to the fact that the tick which carries the disease has not become infected in other localities or that it has not itself entered therein. The climatic conditions present in this geographical location may then have no bearing on the distribution of this disease. The sleeping sickness which has destroyed so many lives in Africa may be confined to that country by the same sort of influence that confines spotted fever to some of our Western states. There are biting flies in various parts of the world which could possibly carry the trypanosome of sleeping sickness quite as easily as the tsetse fly of Africa, if they had the opportunity. There may be no climatic significance in the geographical location of this disease.

In warm climates or in warm seasons stagnant surface water becomes a breeding-place for various lower forms of life. Insect carriers of disease, such as mosquitoes, flourish under such conditions. Various parts of the United States are noted for malaria simply because those localities offer excellent breeding facilities for the malarial mosquito. If this stagnant water is polluted with sewage containing pathogenic organisms, these organisms are likely to remain viable for some time. Fortunately, the competition between pathogenic and non-pathogenic bacteria under such circumstances results in a victory for the non-pathogenic forms. There is danger, however, that the victory may be delayed until after human infection has occurred. Streams that flow rapidly are not such favorable breeding-places for disease-carrying mosquitoes as are those slowly moving, swampy streams that pass through level country. Spring freshets and spring thaws some-

times wash surface sewage into the water supply of cities. This is a common contributory cause of typhoid fever. Subsoil drainage has been known to carry sewage from cesspools and latrines into wells of drinking water. Such drainage contributes to the spread of such diseases as typhoid fever and cholera.

Defense against unfavorable external physical and biological environment.—Scientific information and ingenious enterprise have done much to safeguard human health from the antagonisms of extremes in climate, seasons, weather, and physical geography. The adaptability of home buildings; the availability of equipment for heating, cooling, humidifying, and illuminating human habitations; and the growing custom of wearing comfortable, seasonable clothing adjusted for heat or cold, wind, rain or shine are resources of hygiene that protect human life from these contributory causes of poor health and disease. These defenses of health have played their part in the prolongation of human life. More recent progress in aggressive tropical hygiene has demonstrated the controllability of certain factors in local physical geography favorable to disease that have made some regions of the tropics dangerous for all races and uninhabitable for white races. We have now the scientific information necessary to the control, and in some localities the eradication, of yellow fever, malaria, cholera, hookworm, and typhoid fever. These achievements of aggressive hygiene are largely products of a sanitary control over local conditions in nature that favor the production, distribution, or activity of pathogenic organisms and their carriers.

These advances in hygiene are products of scientific research and rational education. Upon the college man and the college woman rests the responsibility for the greater and more economic utilization of the natural resources of the earth and for the more effective conservation of human life. No college or university graduate can honestly—or honorably—limit his interest or his activity to a merely local application. The world is his field. His special training may take him anywhere for the service which he owes to society in compensation for the greater opportunities that society has given him.

Unfavorable social environment as a contributory cause of disease.—Sources: Social environment is furnished by the groups of which one is a member and by the communities

(societies) of which his groups are constituent parts. Social environment becomes a contributory cause of disease where it is characterized by such influences as congestion of population (in living quarters or in a community), ignorance, illiteracy, poverty, superstition, vice, lawlessness, crime, selfishness, cruelty, and war.

Unfavorable social environment within the group. — This might read "unfavorable internal group environment." We have explained elsewhere in this text that the term "group" is used here to describe a unit of two or more people housed or domiciled for periods of time. The most important group units so far as hygiene is concerned are the home or family group, the school group, and the working group.

Group welfare and group purposes require a place of occupancy that is located, planned, built, equipped, and furnished for the protection and accommodation of the group numbers and their group activities against adverse physical, biological, and social environment. This place of "occupancy" may be a tent, a bungalow, a tenement, a mansion, a one-room school, a shop, an office, a factory, a fort, a battleship, or other arrangement for habitation or for occupational activity.

The formation of a group incurs a group responsibility that rests upon one or more individual members, as, for example, the parent, the teacher or other school official, the owner of the shop, the proprietor of the factory, or the directors of a company or a corporation. Among other things, these responsibilities involve a responsibility for group conditions, group activities, and group regulations that influence the health.

Group constituency or group personnel includes varying numbers of individuals each one of whom adds his personal health problems to the composite health problem of the whole group. Thus, there may be pressures or emphases from such factors as race, family, sex, age; and from economic status, education, religion, and moral standards. Each group member has a responsibility in relation to the group as a whole. This responsibility makes it incumbent upon him to respect the health rights and hygiene welfare of the other members of the group. He must submit to the hygiene regulations and discipline of the group.

Group activities may be described under such classifications as domestic or family or home activities; educational and informational activities; and labor, commercial, and professional activi-

ties. A program of activities in a given group may be scheduled usually under the following headings: work, play, leisure, rest, nutrition, and excretion. The health of the group depends in no small degree upon the composite hygiene of the group schedule.

Group regulations are necessary for the safety and welfare of the group and the community of which the group is a part. These regulations may come to the group from the local, state, or national government to which the group is responsible, or they may be regulations formulated by the group itself. The regulations of the group hygiene involve (1) measures for defense against mechanical, physical, and chemical agents that injure health; (2) regulations for defense against bacterial, protozoan, and other pathogenic organisms and their carriers; (3) regulations for the protection of heredity, age, and sex; (4) regulations for the care of the sick and the injured; (5) regulations providing for the needs of constructive hygiene.

The most important group units so far as hygiene is concerned are the home or family group, the school group, and the working group.

The experience of ages has demonstrated the necessity and the utility of group measures for the preservation of health. Whenever two or more people live or work or otherwise associate together for periods of time they become sources of possible health injury to each other. The purpose that brings them together into group formation, the conditions under which they satisfy that group purpose, and the relations of the group to other groups are additional hazards of health injury. It becomes necessary, therefore, that measures be taken to protect the group members from each other, from the hazards of the group activity and occupation, and from the risks present in the group location and environment. It is obvious that each group member has a serious responsibility for the health safety of every other member. In practice, this obligation is commonly not recognized and even when understood it is frequently ignored. Nevertheless, consciously or unconsciously, a theory and a practice of group hygiene have been developed. Tradition, superstition, experience, scientific information, and education combine to produce standards of group hygiene. The conditions, customs, and internal influences of groups differ in response to variations in the pressures of tradition, superstition, experience, scientific information, and education. In groups

dominated by tradition and superstition, the measures, regulations, customs, and conditions of hygiene are inevitably of low standard. The sick-rate and the death-rate are great. Under the dominion of scientific information and rational education, the health standard of the group is higher. The qualities of health achievement possible in a given group, however, are subject to the hygiene standards (i.e., the laws, ordinances, and enforcements) of the community in which that group is located and of which it is a part.

The applications of the scientific facts of hygiene for the management and control of physical, biological, and social environment in order to preserve health in the home, the school, the working or other group constitute group hygiene.

A failure to apply these facts for the acquisition and conservation of health in a group exposes the group to health hazards.

Such failure may be due to ignorance of the scientific facts of general hygiene or it may be due to an economic inability to provide the defensive measures that are recognized as important or necessary.

It must be said that ignorance, or unbalanced education, and poverty, or inadequate financial resource, are the most important of the group contributory causes of poor health and disease.

It must also be emphasized that either poor individual hygiene or poor intergroup hygiene may destroy the effectiveness of group hygiene. The health of the group depends on the health of all of its members and upon the health of the community of which it is a part. Poor individual hygiene and poor intergroup hygiene are, therefore, contributory causes of poor group hygiene. A single group member with tuberculosis or gonorrhea or typhoid (a bacillus carrier) may ruin the health of the rest of the group. On the other hand, no home group, school group, working group, nor any other sort of a group in the sense in which we are using the term, can permanently maintain the health of its members if it is exposed to a governmental responsibility (intergroup hygiene) that permits the pollution of community drinking water, or neglects the medical inspection of school children, or fails to enforce laws against prostitution, or otherwise abandons its constituent groups to merciless and tragic community influences (unfavorable external environmental influences) over which the single group has no control.

A discussion of the customs, conditions, and influences that produce poor health in a group involves a pertinent consideration of the health hazards that are attached to group housing, group personnel, group activities, and group regulations. These are subjects that belong to a detailed consideration of group hygiene, which may be found in a later division of this text.

Unfavorable social environment within the community.—The community is external to its constituent groups. Its internal environment is their external environment.

We have explained the meaning of our use of the term "intergroup hygiene" for the description of community or social relations that must exist between the groups that form the community. These intergroup relations are inevitable because society or its constituent communities can be formed in no other way than by associations of groups of individuals.

Intergroup hygiene, or societal hygiene, is concerned with the application of the natural laws of hygiene for the control of physical, biological, and social environment for the health welfare of the associated groups of humans that constitute a society or a community. The several groups are dominated by common interests and exposed to common health dangers. They are competent to establish and enforce common standards of individual and group responsibility for community health. Intergroup hygiene includes the hygiene of the rural community, the village, the city, the town or township, the county, the state, the nation, and alliances of nations.

The intergroup relationship is a product of a coming-together of groups for purposes of relative permanency. This very association of groups of humans in governmental entities, protective, cooperative, progressive, aggressive, and constructive though it may be, brings with it and emphasizes various important health hazards.

Constructive and conservative hygiene are, at bottom, problems of nourishment, excretion, work, play, rest, protection, and repair. The intergroup relationship necessarily involves a multiplication of the difficulties of obtaining adequate nourishment (food, water, and air); of disposing of community excretions (sewage); of providing and regulating work, play, and rest; of securing protection against the inanimate, animate, physiological, and contributory agencies and influences that cause disease and

destroy health; of repair and replacement; and of treatment of defects, acute illnesses, and chronic disease.

These increases in the hazards of health form intergroup responsibilities which can be successfully met only by resourceful organization and ample economic support.

The intergroup relationship—the rural community, the village, the town, the city or the township, the county, the state or the nation—means centers of population, densities of population, or congestions of population. It means centers, densities, and congestions of group occupations—the residential community; the university town; the industrial, commercial, or manufacturing city; or the diversified cosmopolitan metropolis. And it means localizations of governing, regulating, and enforcing authority—the national government, the state government, the city government, and other subdivisions of state government.

It is obvious, therefore, that the intergroup contributory causes of poor health and disease are products of population, of occupation, and of inadequate governmental organization.

The more important intergroup contributory causes of poor health and disease are described in the following list.

Unprotected community water supply; unprotected community food supply, particularly milk; open sewage; basement, backyard, alley, and over-the-fence-or-anywhere disposal of garbage, refuse, and litter; street dust and industrial dust; unsanitary street cars, passenger trains, and other common carriers (heat, ventilation, illumination, over-crowding, and cleaning); unsafe buildings, construction, architecture, and equipment; congestion (tenement house, street, school, common transportation service, or shop); disease carriers (insect, animal, and human carriers; prostitution); industrial, occupational, and transportation hazards (the source of most of our accidents and injuries from mechanical, physical, and chemical agencies); poorly equipped general and special hospitals, and clinics; inadequacies of time, space, supervision, equipment, or provision for play and recreation; general ignorance, illiteracy, tradition, superstition, and misinformation concerning health and disease; inadequately informed public officials concerned with public hygiene; pseudo-scientific health teachings, health cults, and health irrationalities in certain religions that gain the public attention; unworthy and unsafe medical practitioners, dental practitioners, nurses, and others whose profes-

sional concern should be with the defense of human life, the conservation of human health, and the maintenance of human happiness.

There should be no such thing in the practice of medicine as poor preparation, commercialism, unethical conduct, dissipation, or lack of dependability. Our requirements for admission to and graduation from medical schools have been too low. It is a misfortune that there cannot be a character test for admission to training or to the practice of medicine in any and all of its divisions. There have been and still are too many poorly trained physicians practicing on the public. Good character is as much a requisite in the practice of medicine as good training. Some states have enacted laws which permit inadequately trained men and women to take responsible control over human life. Various non-medical practitioners are admitted to license in some states. Every precaution should be taken to guarantee that only wisely and efficiently trained medical practitioners are given responsibility in the treatment of disease. Only men and women of good character and good scientific education should serve on our boards of health or otherwise direct our public health activities.

The high cost of health operates to the disadvantage of the community of insufficient financial or economic resources. A pure water supply, good sewers, hospitals, parks, and the control of epidemics are expensive. But when such investments mature, the profit justifies the expenditure.

Travel and commerce serve as distributors of disease. During the epidemic of infantile paralysis in the United States a few years ago, maps charting the progress of the disease clearly showed that it followed the line of railroad distribution. The recent world-wide epidemic of influenza followed routes of international travel. The history of syphilis, bubonic plague, cholera, smallpox, measles, and other important diseases amply illustrates their distribution by caravan routes, ocean ways, and railroad lines.

War is an intergroup influence that interferes with or breaks down our environmental defense against poor health and disease. Except under the most careful rules of military hygiene, war means more deaths from disease than from guns and cannon. History teaches us that the armies of the past have been devastated by smallpox, syphilis, cholera, typhus, typhoid fever, malaria, and

yellow fever. This is due to the fact that military tactics have been slow to include military hygiene. The army created all the favorable conditions for the spread of disease without establishing any effective defenses against disease.

In the Napoleonic wars the armies under that great general lost 400,000 men from gunfire and wounds, 600,000 from disease. The Union Army in our Civil War lost 110,000 men from battle and 224,000 from disease. The Spanish-American War (1898) produced a mortality in the United States Army of seven times as many deaths from disease as from battle. One-third of the entire American force engaged were infected by typhoid fever. In the World War "our total casualties were 318,993, of which number 34,249 were killed in action, 50,714 died from disease, and 13,691 (6.11 per cent) died from wounds out of 224,089 wounded."

Within the last few years military hygiene has come to occupy a place of the highest importance in the management of armies and navies. As a result, our military defenses against disease are now often better than our civilian defenses. It was reported at the annual meeting of the American Public Health Association, 1917, that the occurrence of venereal disease in the regular American Army was less than in the civilian population.

Surgeon-General Ireland stated before the College of Physicians and Surgeons, Philadelphia, February 4, 1921, that

> . . . . although the Union Army of the first two years of the Civil War was one-fourth the size of our mobilization in the World War, nearly 10,000 more men were killed outright in the Civil War, more than 22,000 more men were wounded, more than twice as many died from wounds in hospitals, and nearly four times as many died from the effects of disease. . . . Our capacity to heal wounds has increased twofold and our ability to treat disease, fourfold.

The armies of history not only suffered enormously from disease themselves, but they also carried disease to the civilian population with which they came into contact. In 1813, a war year, the death-rate in Leipzig was trebled. In Paris, in 1814, the defeated army of Napoleon brought to that city an increase in its civilian death-rate from 19,000 to 26,000, exclusive of soldiers. In 1870 Germany was almost free from smallpox. In 1871 thousands of French prisoners were taken into Germany. At that time France was overrun with smallpox. These prisoners

carried the disease into Germany and between 1870 and 1873 over 120,000 deaths from smallpox took place in Germany. The disease history of Russia, Poland, and Far Eastern countries subsequent to the World War gives appalling evidence of the prolonged tragic and massive after-effects of war upon human health.

Immigration: Stringent laws have been enacted to keep disease carriers from entering this country. It is not an easy matter to detect disease in its incipiency. Therefore, disease not infrequently enters the United States by this route. (It is only fair to state that our quarantine measures are more than reasonably effective. For instance, we have had no serious epidemic from this source in years. There has been no cholera since 1873.)

The death-rate from tuberculosis in foreign-born whites is double that of native-born whites in the United States. The later type of immigrant admitted to this country up to the time of the World War was not a healthy, rugged, resistant type which offered a good foundation for a future virile citizenship. Thus, in various ways, immigration may interfere with, break down, or get through our community defenses against disease.

Public carelessness is an influence that breaks down or interferes with our environmental defenses against disease. Many persons who know better spit in public places. Parents not infrequently permit their children while recovering from whooping cough, chicken-pox, measles, scarlet fever, and other communicable diseases to mingle with other children before it is safe for them to do so. Too many people are careless about washing their hands before they eat or before they handle food intended for other people to eat.

If it is true that four per cent of all people that have typhoid fever become chronic carriers of the bacilli that cause that disease, there must be many thousand typhoid carriers in continental United States. A single drop of urine from one of these cases may contain three million typhoid bacilli. Suppose every one of these thousands of carriers is as careless about washing his hands as you are, how safe would they be as milk dealers, bakers, butchers, grocers, waiters, cooks, dishwashers, soda-fountain clerks, confectioners, or cigar makers?

Selfish and unscrupulous business and commercial interests: The newspapers of one of our states, a few years ago, complained bitterly when a health officer made public the fact that bubonic

plague existed in his city, and a business organization in that city took vigorous action to suppress the news of the disease. The same papers were again bitter in their complaint when a little later the State Board of Health published a bulletin showing that malaria was common in that state. Public knowledge of these facts would injure business! More recently, the health officers in another city are said to have reported an unusually large number of cases of chicken-pox, including therewith a number of cases of smallpox. Reporting chicken-pox instead of smallpox was less injurious to the tourist trade with the city.

The United States inspectors from the Bureau of Animal Industry condemn every year as unfit for consumption thousands of animal carcasses which were intended for the market. These officials condemn every year millions of parts of animal carcasses prepared for interstate distribution.

The Board of Health of New York City destroys thousands of quarts of milk each year, thus preventing certain milk dealers from marketing bad milk.

In these and many other ways we have evidence that business and commerce often lead men to adopt policies that are antagonistic to the public health. Such men are willing to suppress the truth at the sacrifice of human life and human health. They often deliberately attempt to circumvent laws enacted for the defense of the public against disease.

Sordid politics sometimes operate to weaken or destroy our intergroup defenses against disease. Local ordinances, state laws, and national legislation have suffered from ulterior motives, inimical to public health. These influences have been particularly evident in relation to such matters as the suppression of prostitution, the control of child labor, the guarantee of pure foods and drugs, the establishment and empowering of departments of health, and the maintenance of high standards of admission to medical practice.

Since the achievement and conservation of quantitative health is a joint product of individual hygiene, group hygiene, and intergroup hygiene, it follows that a weak defensive intergroup hygiene is bound to result in a vulnerable public health. A number of the more important intergroup contributory causes of poor health and disease have been stated. A strong, protective, constructive, aggressive intergroup program will eventually control

these adverse influences. But a strong intergroup hygiene is not possible with: (*a*) Inadequate and ineffective educational hygiene. It is particularly important that the universities, colleges, and normal schools should produce graduates that understand the rationale of hygiene—the relations between cause and effect in health and in disease. From these graduates come our teachers of teachers, our teachers of children, our most intelligent mothers and fathers, and our citizens of influence and power. (*b*) Indifferent measures for training children in health habits. The most important period for the establishment of lasting health habits is the period of childhood and youth—dominated by the home and by the elementary and secondary schools. (*c*) Inadequate provision for an insufficient encouragement of scientific research in the various divisions of hygiene. The scientific facts of hygiene now in practical use have more than doubled the average duration of life in the last two hundred years. Known scientific facts not yet applied would largely increase the saving of life if applied. Unknown and yet-to-be-discovered scientific facts are essential to the more complete protection of life and health. (*d*) Imperfect or inadequate governmental organization and machinery (local, state, or national) for the acquisition and conservation of public health. (*e*) Inadequate or unenforced laws, ordinances, and regulations for the defense of public health. (*f*) Untrained, poorly prepared, or inexpert health officials.

Public, family, and individual health are today products of education, information, economic resource, social organization, and government. Of these ultimate forces, the most powerful are scientific information and education. Information that presents the dominating facts of hygiene, and education that subjects those facts to rational thought and discriminating judgment—these are forces that make for better individual hygiene and for better family hygiene. They are the forces that have compelled social and governmental organization and action in the interest of better public health. They are the forces that have made wise use of economic resource and in the last two hundred years have made investments in health that have enormously increased the productivity and prosperity of the world. In that period of time they have doubled the average duration of human life.

Conversely, the most effective obstacles to the establishment and maintenance of health standards are found in the absence or

insufficiency of education, information, economic resource, social organization, and government. The most important of these are the insufficiencies of education and of information. Ignorance, superstition, irrational judgment, prejudice, misinterpretation, misinformation, and lack of information in relation to hygiene are the greatest of the fundamental contributory causes of poor health and disease. Poverty, inadequate financial resource, and the high cost of health are hardly less compelling in their merciless influences on hygiene; carelessness, indifference, selfishness, vice, delinquency, and crime are impediments to protective social organization and are common associates with ignorance, uneducated judgment, and hygiene illiteracy. Imperfections, inadequacies, and futilities of protective social measures and of governmental efforts for the control of health, when they occur, are results of these influences. They are effective obstacles to the achievement and maintenance of individual, group, and public health standards.

These anti-social forces constitute the basic influences that contribute to the production of poor health. They devitalize the nation. They waste the vigor of youth and the capacity of maturity. They damage the home and they impair the individual. Hence, our national physiological scrapheap. Hence, the military discard into which we threw one-third of our boys, at the time of the World War—physically unfit for military service in the very flower of young manhood. And the demands of peace are more exacting and more merciless, even if more subtle, than those of war!

CHAPTER XLI

MODERN SCIENTIFIC HYGIENE AND ITS ACHIEVEMENTS AND FAILURES[1]

Increase in longevity consequent on the rise of modern scientific hygiene.—With the improvement and application of the microscope and the perfection of microscopical technique an immense new field of biological research was found and its exploration begun in the nineteenth century. Accurate information concerning many of the great determining facts of cause and effect in the heredity and experience of living things was then added to the store of human knowledge and to the educational resources of the university, the college, and the professional school. Within the last century the public use of this information has so contributed to the increase of life expectancy in the advanced countries of the world that the expectation at birth now ranges in those countries from fifty-six to sixty years, a gain of twenty years or more in less than a century. Many of the causes of health and disease, having been identified and carefully studied, are now well understood. This scientific information or a part of it has reached a portion of the intelligent public and has replaced some of the ignorance and tradition that were so powerless to protect life and health in the preceding centuries. But those countries in which scientific health information has not influenced societal usages, beliefs, customs, and laws are still paying the penalty of ignorance of scientific hygiene. For instance, the life expectancy at birth in India now is reported as twenty-five years.

Whenever the great public really learns any of the unvarying relations of cause and effect in health and in disease the mandate of public opinion puts that knowledge into stern application. Within the past century the public has derived much beneficial health information from its educational institutions and has used a part of the products of scientific research and of tested human experience in the formulation of its health standards, the establishment and maintenance of its sanitary engineering projects, and the regulation of its health practices. The average life ex-

[1] Taken from report on *The Status of Hygiene Programs in Institutions of Higher Education in the United States,* Thomas A. Storey (Stanford University Press, 1927), pp. 16–19.

pectancy at birth in the enlightened communities of the world has been increased by more than seventy per cent since the eighteenth century.

This increase in life expectancy is probably due to the combination of a variety of influences. There can be no question that the most important and the greatest of these influences have come out of the biological information that has been developed through research activities in higher educational institutions and distributed thence to better educated citizens, physicians, teachers, and school children, and finally applied for the benefit of the general public because of the demands of informed leaders and their supporting constituents. The pertinent facts from the biological sciences (with their psychological and sociological inclusions) furnish the only dependable sources for the sciences and arts of hygiene; for the hygiene practice of the individual, the family, and the public; for the mental and bodily hygiene of religion, medicine, dentistry, and nursing; for the planning and administration of public health service and its sanitary engineering projects; and for the plans and specifications of all other activities concerned with human welfare.

These increases in the life expectancy are due largely if not wholly to decreases in the occurrence of preventable disease and avoidable death. Large decreases in the death-rate of infants and in the deaths of mothers at childbirth are outstanding products of scientific information applied by the general public in response to the influence of men and women of educated intelligence—the leaders of public thought and public action. The diseases about which we know most are being slowly controlled and their morbidity and mortality rates decreased. Wherever public opinion has authorized and supported the rational application of scientific information, there has followed a conservation of human health. Education and scientific information have thus influenced the public in the enlightened nations of the earth to reduce the occurrence and death-rate of tuberculosis, typhoid and paratyphoid fevers, malaria, smallpox, typhus, bubonic plague, cholera, yellow fever, diphtheria, and, under certain circumstances, notably in the American Army and Navy during the World War, gonorrhea and syphilis. Thus our knowledge of the communicable diseases enables us to control those diseases through the power of informed public opinion.

Our knowledge of the diseases caused by physical and chemical agents (chiefly the accidental injuries and deaths from vehicular traffic, railroad transportation, mining, and manufacture), our growing knowledge of the mental and nervous causes of disease, our increasing knowledge of deficiency and deprivation as causes of disease, and our knowledge of defenses against cancer in its early stages are all becoming available increasingly for public information and public use.

Current evidence of deficient educational hygiene.—But with all this gain and with all this promise of further new scientific information there is plenty of ugly evidence that the public even now is unaware of much important available information concerning the causes and care of health and disease. There is much prejudice against scientific research, much ignorance of present values of scientific hygiene and of the fact that there is yet an enormous amount of scientific truth to be discovered.

Ignorance, tradition, prejudice, and superstition are with us yet. Primitive and ancient mores persist. The higher education of the shamans, medicine men, magicians, and priests that influenced public opinion and public action in Mesopotamia, India, Arabia, Egypt, and Homeric Greece influences public opinion and public practice to an extent even today. We have magicians who make rain or locate wells. Quack doctors are common. Cults flourish. The uncritical use of patent medicines and nostrums is enormous. Six per cent of our population can neither read nor write and have behind them an unbroken ancestry whose folklore and mores unite them with the magicians, priests, and medicine men of prehistoric education. Some fifteen millions of our people cannot read intelligently nor write intelligibly. And the great majority of the public avoids the hard work of real thinking when problems of health present themselves.

Two thousand people die every day of preventable disease in the United States. In 1932, 121,267 infants under one year of age died in the birth registration area in this country.[1] Tuberculosis destroyed 75,509 lives in the area of registration[2] in 1932;

[1] *Mortality Statistics, 1932,* United States Bureau of the Census. The "birth registration area" is made up of those states that furnish birth records whose accuracy is recognized by the United States Bureau of the Census.

[2] *Ibid.* The "area of registration" in 1932 included forty-seven states, the District of Columbia, and the territories of Hawaii, Puerto Rico, and the Virgin Islands. This is the area of death registration.

accidental and unspecified external causes killed 85,868 persons; syphilis, over ten thousand; diphtheria, more than five thousand; and measles, almost two thousand. All these were preventable deaths. The Playground and Recreation Association of America reports that seven thousand children were killed in 1924 on streets and highways in the United States. It is estimated that two per cent of the entire population is sick-a-bed at any time and that at least fifty per cent of that sickness is preventable. In 1928 there were 38,432 cases of smallpox reported in the United States. The prevention of these avoidable diseases and deaths will be accomplished when the information now available becomes a part of the usages, customs, beliefs, and regulations of the home, the school, the factory, the office, and the community, and when it governs societal behaviors and determines sanitary and other health-preserving investments as a part of the mores, institutions, and laws of the people.

In addition, we have diseases and deaths the causes of which are not yet well known. The information necessary to effective public action for their control is increasing, though as yet far from complete. Cancer was responsible for 122,739 deaths in the area of registration in 1932. Many lives would be saved and much pain and suffering avoided if the information we now have covering the curability of early cancer by radical surgical treatment were known and used by the public.

Over 395,000 patients with mental diseases were under treatment in hospitals in the United States in 1929. In 1927 over 70,000 new cases were admitted to our hospitals for the insane.[1] It is estimated that one person out of twenty-five becomes insane at some period of life. We do not yet know how much of this human injury is preventable nor how much is controllable. The psychologist and the psychiatrist have learned a great deal about mental hygiene in recent years. The prevention, care, and control of mental disease is being rapidly improved. Dr. Earl D. Bond, reporting on 1,054 consecutive cases admitted to the Department of Mental Diseases, Pennsylvania Hospital, states that 25.9 per cent were discharged well and were maintaining their full return to function at the time of his report five years afterward. Fifteen

[1] National Committee on Mental Hygiene, 50 West Fiftieth Street, New York City.

per cent were improved.[1] But even the little information that science has furnished to date has largely failed to reach the great public, and the preventable waste of health and life through mental disease goes on largely unchecked.

Finally, every group of infants, children, youths, adults, or aged of either sex ever examined with scientific care has shown statistically a considerable occurrence of remediable physical defects, faulty health habits, and preclinical diseases. The most outstanding and dramatic of this evidence of the failures of the hygiene programs of higher education was furnished by the wholesale examinations of young men for military service during the World War. In the United States approximately one-third of these men were rejected because they were found unfit for service at a time of life in which they should have been at their best, physically and mentally. A considerable proportion of this deficiency was preventable, penalizing young men for somebody's careless neglect or ignorance.

Thus, incontrovertible evidence indicates that the public, of which we are responsible though dependent members, is even now far from well informed. The knowledge that science has gathered has not found its way sufficiently into the beliefs and habits of the people where it must be common knowledge before it can be used successfully for the promotion and defense of public health. Much "teaching" remains to be done by our institutions of higher education if the scientific health-defending and health-producing information now stored in the literature, laboratories, and health professions is to become more completely the possession of the public, included in its beliefs, absorbed into its usages and customs, and applied in its service. There is much important health information that the scientific laboratories of higher educational institutions may be encouraged yet to find and place at the disposal of society.

[1] Earl D. Bond, "Underestimation of Good Results in Mental Disease," *Journal of the American Medical Association,* August 15, 1925.

APPENDIX

APPENDIX A. TABLES OF WEIGHTS AND MORTALITY

STANDARD TABLE OF HEIGHTS AND WEIGHTS—MEN

Top and bottom figures in each square are 20 per cent under and over the average.

Heights		Weights According to Age Period								
Feet	Inches	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59
		89	94	98	100	102	104	106	106	107
4	11....	111	117	122	125	127	130	132	133	134
		133	140	146	150	152	156	158	160	161
		90	95	99	102	103	106	107	108	109
5	0....	113	119	124	127	129	132	134	135	136
		136	143	149	152	155	158	161	162	163
		92	97	101	103	105	107	109	110	110
5	1....	115	121	126	129	131	134	136	137	138
		138	145	151	155	157	161	163	164	166
		94	99	102	105	106	109	110	111	112
5	2....	118	124	128	131	133	136	138	139	140
		142	149	154	157	160	163	166	167	168
		97	102	105	107	109	111	113	114	114
5	3....	121	127	131	134	136	139	141	142	143
		145	152	157	161	163	167	169	170	172
		99	105	107	110	112	114	115	116	117
5	4....	124	131	134	137	140	142	144	145	146
		149	157	161	164	168	170	173	174	175
		102	108	110	113	115	117	118	119	120
5	5....	128	135	138	141	144	146	148	149	150
		154	162	166	169	173	175	178	179	180
		106	111	114	116	118	120	122	122	123
5	6....	132	139	142	145	148	150	152	153	154
		158	167	170	174	178	180	182	184	185
		109	114	117	119	122	123	125	126	126
5	7....	136	142	146	149	152	154	156	157	158
		163	170	175	179	182	185	187	188	190
		112	117	120	123	126	127	129	130	130
5	8....	140	146	150	154	157	159	161	162	163
		168	175	180	185	188	191	193	194	196
		115	120	123	126	130	131	133	134	134
5	9....	144	150	154	158	162	164	166	167	168
		173	180	185	190	194	197	199	200	202
		118	123	126	130	134	135	137	138	138
5	10....	148	154	158	163	167	169	171	172	173
		178	185	190	196	200	203	205	206	208
		122	126	130	134	138	140	142	142	143
5	11....	153	158	163	168	172	175	177	178	179
		184	190	196	202	206	210	212	214	215
		126	130	135	139	142	145	146	147	148
6	0....	158	163	169	174	178	181	183	184	185
		190	196	203	209	214	217	220	221	222
		130	134	140	144	147	150	152	153	154
6	1....	163	168	175	180	184	187	190	191	192
		196	202	210	216	221	224	228	229	230
		134	138	145	149	153	155	158	158	159
6	2....	168	173	181	186	191	194	197	198	199
		202	208	217	223	229	233	236	238	239
		138	142	150	154	158	161	163	164	165
6	3....	173	178	187	192	197	201	204	205	206
		208	214	224	230	236	241	245	246	247

STANDARD TABLE OF HEIGHTS AND WEIGHTS—WOMEN

Top and bottom figures in each square are 20 per cent under and over the average.

Heights		Weights According to Age Period								
Feet	Inches	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59
		88	90	93	98	98	101	103	105	106
4	11....	110	113	116	119	122	126	129	131	132
		132	136	139	143	146	151	155	157	158
		90	92	94	97	99	102	105	106	107
5	0....	112	115	118	121	124	128	131	133	134
		134	138	142	145	149	154	157	160	161
		91	94	96	98	101	104	106	108	110
5	1....	114	117	120	123	126	130	133	135	137
		137	140	144	148	151	156	160	162	164
		94	96	98	100	103	106	109	110	112
5	2....	117	120	122	125	129	133	136	138	140
		140	144	146	150	155	160	163	166	168
		96	98	100	102	106	109	111	113	114
5	3....	120	123	125	128	132	136	139	141	143
		144	148	150	154	158	163	167	169	172
		98	101	103	106	109	111	114	115	117
5	4....	123	126	129	132	136	139	142	144	146
		148	151	155	158	163	167	170	173	175
		101	103	106	109	112	114	117	118	120
5	5....	126	129	132	136	140	143	146	148	150
		151	155	158	163	168	172	175	178	180
		104	106	109	112	115	118	121	122	122
5	6....	130	133	136	140	144	147	151	152	153
		156	160	163	168	173	176	181	182	184
		107	110	112	115	118	121	124	126	126
5	7....	134	137	140	144	148	151	155	157	158
		161	164	168	173	178	181	186	188	190
		110	113	115	118	122	124	127	130	130
5	8....	138	141	144	148	152	155	159	162	163
		166	169	173	178	182	186	191	194	196
		113	116	118	122	125	127	130	133	134
5	9....	141	145	148	152	156	159	163	166	167
		169	174	178	182	187	191	196	199	200
		116	119	122	124	127	130	133	136	138
5	10....	145	149	152	155	159	162	166	170	173
		174	179	182	186	191	194	199	204	208
		120	122	124	126	130	133	136	139	142
5	11....	150	153	155	158	162	166	170	174	177
		180	184	186	190	194	199	204	209	212
		124	126	127	130	132	135	138	142	146
6	0....	155	157	159	162	165	169	173	177	182
		186	188	191	194	198	203	208	212	218

LIMITS OF OVERWEIGHT CORRESPONDING TO VARIOUS MORTALITY RATIOS*

Heights Feet	Inches	Mortality Ratios	20–24	25–29	30–34	35–39	40–44	45–49	50–53	54–56	57–59
5	1	100	144	137	131	129	128	130	131	130	129
		110	160	149	138	138	140	140	142	142	142
		120	166	159	147	149	150	151	151	152	152
		125	167	160	154	152	152	154	156	157	157
		135	173	166	161	159	159	161	162	163	163
		140	177	170	165	162	163	163	166	166	168
		150	182	175	167	168	169	170	171	174	174
		160	187	183	178	175	175	176	177	181	181
5	2	100	149	141	135	134	133	135	135	135	134
		110	163	152	144	143	145	145	147	147	147
		120	169	162	151	153	155	155	155	156	156
		125	171	163	158	157	156	158	160	161	161
		135	177	170	165	163	163	165	167	167	167
		140	180	173	168	166	166	168	170	171	172
		150	187	179	172	172	173	175	176	178	178
		160	192	187	181	179	178	180	181	185	185
5	3	100	153	146	141	140	139	141	141	141	140
		110	166	157	150	149	150	151	153	153	153
		120	173	166	157	158	160	160	161	162	162
		125	175	168	163	160	161	163	165	165	166
		135	181	175	170	168	168	170	172	173	174
		140	185	178	173	171	171	173	175	176	177
		150	191	183	177	177	178	180	181	183	183
		160	197	191	186	184	183	186	187	190	191
5	4	100	158	151	147	147	146	147	147	147	146
		110	169	161	156	156	155	157	158	159	159
		120	177	170	163	164	165	165	167	168	168
		125	180	173	168	167	167	169	171	171	172
		135	186	180	175	174	173	176	178	179	180
		140	190	183	178	177	176	179	181	182	183
		150	196	188	183	183	183	185	187	189	189
		160	202	196	191	190	188	191	193	196	197

Weights According to Age Period.

* Based on *Medico-Actuarial Reports, 1912–1918.*

LIMITS OF OVERWEIGHT CORRESPONDING TO VARIOUS MORTALITY RATIOS*—*Continued*

Heights		Mortality Ratios	Weights According to Age Period								
Feet	Inches		20–24	25–29	30–34	35–39	40–44	45–49	50–53	54–56	57–59
5	5...	100	163	156	153	153	152	154	154	154	152
		110	173	166	162	162	162	163	164	165	165
		120	182	174	170	170	171	171	173	174	174
		125	185	178	174	173	173	175	177	178	178
		135	191	185	181	180	179	182	184	185	186
		140	195	188	184	183	182	185	187	188	189
		150	201	194	190	190	190	191	194	196	196
		160	207	201	197	196	194	197	200	202	204
5	6...	100	166	160	159	159	159	160	161	161	161
		110	177	170	168	168	168	170	171	172	173
		120	186	179	176	176	176	178	180	181	182
		125	189	183	180	179	179	181	183	185	185
		135	196	190	187	186	185	188	190	192	193
		140	200	193	190	189	188	191	193	195	196
		150	206	200	197	196	196	197	200	202	203
		160	212	206	203	202	200	203	206	209	210
5	7....	100	168	164	164	164	165	166	167	168	168
		110	179	175	173	173	174	176	177	178	179
		120	189	183	181	181	182	184	186	187	188
		125	192	188	186	185	185	187	189	191	192
		135	199	195	193	192	191	194	196	198	199
		140	203	198	196	195	194	197	199	201	202
		150	209	205	203	201	201	203	206	208	209
		160	215	211	208	207	206	209	212	215	216
5	8....	100	170	167	168	169	170	172	173	175	175
		110	181	178	178	179	179	182	183	184	185
		120	191	187	186	187	188	190	192	193	194
		125	195	192	191	190	191	193	196	197	198
		135	203	199	198	198	198	200	203	204	205
		140	207	202	201	201	201	203	206	207	208
		150	212	209	208	207	207	209	212	214	215
		160	218	215	213	213	212	215	218	221	223

* Based on *Medico-Actuarial Reports, 1912–1918.*

LIMITS OF OVERWEIGHT CORRESPONDING TO VARIOUS MORTALITY RATIOS*—*Continued*

Heights		Mortality Ratios	Weights According to Age Period								
Feet	Inches		20–24	25–29	30–34	35–39	40–44	45–49	50–53	54–56	57–59
5	9....	100	173	171	171	173	174	176	177	179	180
		110	182	180	181	184	184	186	188	189	191
		120	192	189	189	192	192	194	196	197	199
		125	196	194	193	194	195	198	200	202	203
		135	205	202	202	202	203	205	208	209	210
		140	209	206	205	205	206	208	211	212	214
		150	214	212	211	211	211	215	217	219	221
		160	221	218	217	217	217	220	223	226	228
5	10....	100	176	175	175	176	177	180	181	183	184
		110	181	181	184	187	188	190	192	193	195
		120	192	191	192	195	196	197	199	201	203
		125	197	195	196	198	199	202	204	206	208
		135	206	204	204	206	207	209	213	214	215
		140	210	208	208	209	210	212	216	217	219
		150	216	215	214	214	215	219	222	224	226
		160	223	221	221	221	221	225	228	231	233
5	11....	100	†	†	†	†	179	183	185	187	189
		110	180	182	186	189	192	194	196	197	199
		120	193	193	194	198	199	201	204	206	208
		125	198	197	199	201	203	206	208	211	213
		135	207	205	206	209	210	213	216	219	220
		140	211	209	210	212	213	217	220	222	224
		150	218	217	216	217	219	223	227	229	232
		160	225	224	224	224	225	230	233	236	238
6	0....	100	†	†	†	†	181	186	189	190	192
		110	179	183	188	191	195	197	200	201	203
		120	193	195	196	201	203	205	208	211	213
		125	199	201	204	207	210	213	216	216	218
		135	208	207	208	212	214	217	219	223	225
		140	213	211	212	215	216	221	223	226	229
		150	220	219	219	221	223	227	231	233	236
		160	227	227	227	228	229	234	238	241	243

* Based on *Medico-Actuarial Reports, 1912–1918.*

† At these heights and ages, all overweights are over 100 per cent mortality.

LIMITS OF OVERWEIGHT CORRESPONDING TO VARIOUS MORTALITY RATIOS*—*Concluded*

Heights (Feet Inches)	Mortality Ratios	Weights According to Age Period 20–24	25–29	30–34	35–39	40–44	45–49	50–53	54–56	57–59
6 1....	100	†	†	†	†	184	190	193	194	196
	110	180	185	191	194	198	202	204	205	208
	120	195	199	200	204	207	210	213	217	219
	125	201	201	204	207	211	215	218	222	224
	135	209	208	209	212	217	222	223	228	231
	140	216	213	215	218	221	226	228	232	235
	150	223	222	222	224	226	231	235	238	241
	160	229	230	230	231	232	238	243	246	249
6 2....	100	†	†	†	†	188	193	199	200	202
	110	180	187	193	197	201	205	208	210	212
	120	196	200	202	209	213	215	219	222	225
	125	202	204	207	211	216	219	223	227	229
	135	210	211	212	216	221	227	228	232	236
	140	218	216	217	221	225	230	232	235	240
	150	225	225	225	228	230	236	239	244	246
	160	231	233	233	236	237	244	248	252	254

* Based on *Medico-Actuarial Reports, 1912–1918.*
† At these heights and ages, all overweights are over 100 per cent mortality.

ADDITIONS TO MORTALITY RATIOS FOR OVERWEIGHTS WITH EXCESS ABDOMINAL GIRTHS

Abdominal Girth	Ratios, 100% to 140% inclusive: Under Age 40	Age 40–50	Age 50 and over	Ratios, 150% and 160%: Under Age 40	Age 40–50	Age 50 and over
1-inch excess........	0	0	5	0	5	10
2-inch excess........	0	5	10	5	10	15
3-inch excess........	5	10	15	10	20	25
4-inch excess........	10	15	25	20	30	40

Directions: Use for males and for females. Drop fractions of an inch, ½ inch or less; over ½ inch, use next inch. Overweights whose abdominal girth exceeds the expanded chest girth should receive additions to mortality ratios as per table above.

The tables on this and the preceding pages are used by permission of the Metropolitan Life Insurance Company, New York.

APPENDIX B. CLASSIFICATION OF MENTAL DISEASES

Classification of Disturbances of Mental Health.—The following description of the more important disturbances of mental health and their symptoms has an important place in a text on the principles of defensive hygiene written for the information of the lay citizen. It is the lay citizen who will eventually force the higher standards of individual, family, community, and public hygiene that will ultimately measurably prevent avoidable mental disease, take much better care of those who are mentally sick, and more successfully protect the happiness of those who are well. The intelligent lay citizen will leave the diagnosis of these maladjustments and diseases to the scientifically educated and specially experienced physician on whom he will call for help for the wise solution of the problems of mental health that are otherwise insolvable to him.

The disturbances of mental health (all personality diseases or disorders) may be classified into four large groups. These personality disorders are called psychoses. The four groups are: Group One, the affective, paranoiac, paranoid, schizophrenic, and psychoneurotic disorders; Group Two, the toxic psychoses; Group Three, the organic psychoses; and Group Four, the constitutional inferiority psychoses.[1]

Group One (largely due to psychological causes). The affective psychoses.—Disturbances of mood or state of feelings are the essential characteristics. The affective psychoses are commonly known as manic-depressive psychoses. They include from ten to fifteen per cent of all psychoses; occur at any age after ten years, the majority of cases being between fifteen and forty years of age. The symptoms are exaggerations of normal moods and their variations. One phase of the affective psychoses is known as manic and the other as the depressive phase.

The manic phase.—This phase is a state of more or less pleasant excitement. It may be mild (the hypomanic condition), resembling the beginning of alcoholic intoxication, or it may be characterized by an intense, prolonged over-activity, interfering with eating, sleeping, or resting. Talkativeness, filthy behaviors, destructiveness, violence, mental confusion, illusions, and hallucinations are common.

The depressive phase.—The two phases are opposites. They may alternate or be mixed. The depressive phase is a more or less painful emotional state in which all the functions of the individual are retarded. In its mild form it is characterized by prolonged low spirits, "the blues," sadness, discouragement, gloominess. There is lessened activity, disinclination to talk, feeling of inadequacy, apprehension, loss of interest, lack of initiative, slow thinking, and feelings of unreality. The day's work is done reluctantly and only with effort. Suicide is commonly contemplated and attempted. In its marked form the depressive stage is characterized by exaggerations of the depressive symptoms just described for the mild form.

[1] The descriptions of these classifications that follow are patterned after the text on *Essentials of Psychiatry* by George W. Henry, M.D. (Williams & Wilkins Company, 1925).

The most pronounced state of the depressive phase is a state of stuporous retardation with inactivity, silence, marked confusion, and painful dreams. The individual may become helpless and have to be fed.

The outlook for recovery in the affective psychoses is usually good.

The paranoiac and paranoid psychoses.—The paranoiac psychoses are disturbances of mental health characterized by fixed delusions that have been organized and systematized by the patient. The paranoid psychoses differ from the paranoiac in that they are transient. The paranoiac and paranoid psychoses aggregate from two to seven per cent of all psychoses. Of the two the paranoiac are the less common.

The paranoiac is a victim of conflicts that incessantly occur between his personality and his environment. His personality in his early life is often recorded as "quiet, reserved, shy, self-conscious, and lacking in self-confidence, but at the same time sensitive, proud, determined, ambitious, selfish, and often unusually intelligent."[1] Such or similar personalities come easily into conflict with environment. "They become irritable, querulent, aggressive, or defensive . . . . disappointments and failures lead to distrust . . . . or to suspiciousness; this, in turn, leads to definite delusional thinking or interpretation with the conclusion that the environment is chronically unfair. This process may be elaborated indefinitely until the unalterable conviction is reached that certain or all persons or their agents are engaged in efforts hostile to the individual's welfare. In short, their *delusions become systematized*. . . . . At the final stage in the struggle for the preservation of self-esteem and feelings of superiority, the convictions that they have been persecuted are used as a basis for *further delusions of self-importance and grandeur*."[2]

Paranoiacs are described as of several types, the more important of which are: "(*a*) the persecutory type, which is the most common, characterized by delusions of persecution; (*b*) the grandiose type, that displays delusions of self-importance, such as royal or divine descent; (*c*) the erotic type, characterized by delusions of impossible courtship and marriage; and (*d*) the querulent type with delusions of injustice."[3]

Schizophrenic psychoses.—The term "dementia praecox" has been commonly used to cover these psychoses. They are of insidious onset, occurring usually in the adolescent period. They commonly exhibit a slow mental deterioration. From fifteen to twenty-five per cent of all psychoses are schizophrenic, occurring most commonly between the ages of eighteen and thirty-five.

The symptoms of these psychoses are classified as of the paranoid, catatoniac, hebephrenic, and simple types. The paranoid type is characterized by (*a*) transient delusions of persecution or grandeur; (*b*) hallucinations; and (*c*) progressive mental deterioration. The catatoniac type exhibits peculiarities of psychomotor functions, expressed while the patient is in a state of excitement or of stupor (catatoniac excitement and catatoniac stupor). In catatoniac excitement the psychomotor activity is usu-

[1] George W. Henry, M.D., *op. cit.*, p. 42.

[2] *Ibid.*

[3] *Ibid.*, p. 43.

ally above normal and exhibits "impulsive, odd, stereotyped behavior with more or less definite hallucinations. In the stuporous phase, the total amount of psychomotor activity is definitely less than normal. In marked conditions the patient lies in bed with eyes closed or open and has no apparent contact with the surroundings."[1] The hebephrenic type appears usually in early adolescence and is characterized by shyness, sullenness, and self-absorption or by irritability, obstinacy, rudeness, and assertiveness. "As the symptoms become more marked there is usually such silly behavior as inappropriate smiling, laughter, grimacing, peculiar mannerisms, and peculiar, changeable, grotesque, and absurd ideas."[2] Hallucination and unsystematized delusions may be present.

The simple type of the schizophrenic psychoses is insidious, not only in its onset, but also in its progressive mental deterioration "of a type which proceeds gradually and imperceptibly to a condition of apathy and evident dementia. This change occurs without any special emotional disorder, trend of thought, or expression of delusions or hallucination. Throughout the illness there is often more or less peculiar behavior."[3]

The psychoneuroses.—"The psychoneuroses are disorders in which instinctive and emotional difficulties are manifested under the guise of apparently unrelated mental and physical symptoms."[4] They are very common. They occur most frequently between puberty and middle age. They may be classified as neurasthenia, anxiety neurosis, hysteria, psychasthenia, and traumatic neurosis.

Neurasthenia is characterized by ease of mental and physical fatigability, exhaustion, and prostration. The symptoms include irritability, loss of power of concentration, and inability to carry on a normal program of work without great effort. The neurasthenic complains of many illnesses with little or no organic reason for them.

The anxiety neurosis is evident in morbid anxieties. The patient may be aware of the fact that there is no organic basis or no real reason for apprehension. There may be dread of impending calamity. These morbid feelings may at times be extreme and the patient may expect death. "Acute attacks resemble conditions of extreme fright and are characterized by such symptoms as pallor, tremor, perspiration, palpitations, widely dilated pupils, nausea, incontinence of urine and feces, and dizziness. The patient may even lose consciousness."[5]

Hysteria is characterized by a great variety of symptoms. They include localized or generalized motor and sensory disturbances accompanied by more or less confusion and sometimes by partial or complete loss of memory. These symptoms do not correspond to any recognized physical disorder. They include "weaknesses, paralyses, contractures, and peculiar postures of various parts of the body accompanied by more or less sensory disturbance in the form of increased or decreased sensitiveness. . . . ."[6]

[1] *Ibid.*, p. 50. [2] *Ibid.*, p. 51. [3] *Ibid.*
[4] *Ibid.*, p. 56. [5] *Ibid.*, p. 59. [6] *Ibid.*

Psychasthenia is characterized by compulsions, obsessions, phobias that involve morbid doubts, fears, and impulses.[1]

Traumatic neurosis is produced by trauma—a blow on the head, for instance. There may be a physical injury or there may be only an emotional shock. Apprehension may be aroused. The anxiety may lead to symptoms of neurasthenia, hysteria, or hypochondriasis.

Group Two (largely due to toxic causes). The toxic psychoses.—Poisonous substances entering the body or formed within the body may produce psychoses. "Probably the most constant symptoms are disturbances of consciousness, varying from mild confusion to delirium, or from drowsiness to coma. Other common symptoms are restlessness, depression, hallucinations, delusions, and often bizarre symptoms which, in the absence of toxic substances, would suggest deteriorating psychoses. There are practically always definite accompanying physical symptoms. These vary from feelings of weakness or fatigue to a condition of exhaustion or collapse. Convulsions are not uncommon in some instances."[2]

Endogenous toxic psychoses.—Among the toxic psychoses from internal poisons are those that arise in consequence of infectious disease, exhaustion due to "hemorrhage, starvation, excessive physical and mental exertion, chronic wasting disease, and lack of recreation, rest, or sleep."[3]

Among other endogenous sources of toxic psychoneuroses are excessive or deficient secretions from the endocrine glands. This connection has been proved particularly in relation to the thyroid glands.

The exogenous toxic psychoses.—Among the more common poisons from the outside that cause psychoses are alcohol, opium, morphine, cocaine, and lead. Of these, alcohol is the most important. About ten per cent of all psychoses are alcoholic psychoses. The more common abnormal or psychotic states caused by alcoholic excesses are drunkenness, delirium tremens, and acute alcoholic hallucinations (hallucinosis).

Group Three. The organic psychoses.—This title covers the psychoses that are acquired because of destruction of the cells of the brain. These psychoses constitute about twenty per cent of all psychoses.[4] The conspicuous symptoms of the organic psychoses are defects of memory and of judgment. Mental deterioration is common. Among the more common types of organic psychoses are traumatic psychoses, senile psychoses, and psychoses caused by syphilitic infection of the gray matter of the brain (general paresis).

Group Four. The constitutional inferiority psychoses.—In this group the congenital mental defectives are the most important. This group is a very large one. It is made up of those individuals who are without intelligent mind or with limited potential intelligence, and whose educability is consequently limited. It includes the defectives classified as idiots, imbeciles, feeble-minded, and morons.

[1] George W. Henry, M.D., *op. cit.*, p. 60. [2] *Ibid.*, p. 70.
[3] *Ibid.*, p. 71. [4] *Ibid.*, p. 81.

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